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SOME STRATIGRAPHIC AND STRUCTURAL FEATURES OF THE PRE-CAMBRIAN OF NORTHERN QUEBEC[1]

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PART I

INTRODUCTION

In the present paper the writer will describe briefly the known geology of that part of northern Quebec whose four corners are the north end of Lake Timiskaming, James Bay, Lake Mistassini, and Lake St. John, with the particular object of setting forth the stratigraphic sequence and age relations of its ancient volcanic and sedimentary rocks.

This region is of especial interest on account of its development of rocks of early pre-Cambrian age. The relations existing between these rocks are shown very fully and satisfactorily, and their examination enlarges our knowledge of pre-Cambrian history and introduces corresponding changes in nomenclature. Structural work in this region, as described in this paper, demonstrates (1) a uniform sequence of extrusion in the lavas, termed the Abitibi

[1] Published by permission of the Geological Survey of Canada.

volcanics, which form the basal rocks of the region; (2) the existence of a thick sedimentary series, the Nemenjish series, which lies, so far as results at hand indicate, conformably on the surface of the lavas, and which appears to correspond to the Grenville series; (3) the occurrence of a second sedimentary series, the Mattagami series, in scattered patches unconformably on the surface of the older lavas and sediments. All of the rocks mentioned are older than the Cobalt series of the Timiskaming district, and are probably of pre-Huronian age, using the term "Huronian" as defined by the International Committee. The basal series of lavas may be of the same age as the Keewatin of the south shore of Lake Superior. The younger series of sediments (Mattagami) appears to occupy a new position in the geologic column, hitherto unfilled, between the Keewatin and the Lower Huronian of the International Committee's classification.

The region approximates in shape a rectangle 270 miles from north to south, and 350 miles from east to west (Fig. 1). Since 1908, the western third of it has been studied in considerable detail by M. E. Wilson, J. A. Bancroft, and T. L. Tanton; the greater part of the remainder has been rapidly examined by reconnaissance methods by the writer. In addition, the Chibougamau Mining Commission has examined a limited area around Lake Chibougamau in detail, and J. A. Dresser has similarly studied an area around the south end of Lake St. John. The northern Quebec region connects on the southwest with the Cobalt-Sudbury-Lake Huron region, which has been mapped in detail by Miller and Knight and W. H. Collins, so that a correlation of the whole Lake Huron-Cobalt-northern Quebec region presumably may be attempted in the near future.

This paper is merely a preliminary attempt to piece together some of the fragments of the pre-Cambrian record. The reader should remember the difficulties of deciphering this record, since the areas of ancient rocks are frequently small and disconnected, and the rocks themselves have commonly been sheared and recrystallized. As work is carried over larger areas and the number of facts for piecing out the record becomes greater, many of the conclusions stated in this paper will undoubtedly be modified or discarded. The writer considers, however, that such a concrete

generalized conception as he endeavors to present is of value, even if not wholly correct. In the words of Van Hise:[1] "The attempt to give a generalization . . . . sharpens the wits and makes the geologist think of relations which were not before observed. . . . .

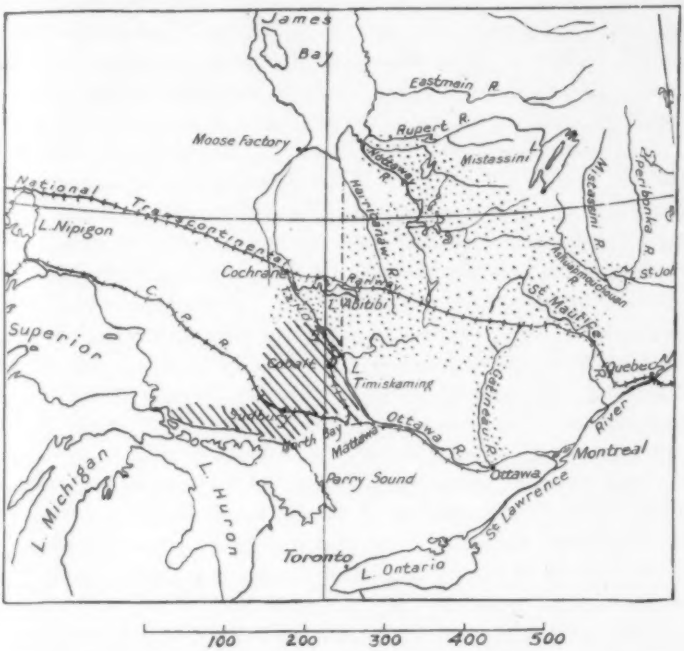

FIG. 1. Work done since 1908 in northern Ontario and Quebec. Dotted areas covered by reconnaissance methods; hatched area, by detailed methods.

He has an hypothesis or hypotheses which he is either to verify or disprove, and consequently will work with greater keenness and insight."

PREVIOUS WORK AND CORRELATION

The northern Quebec region has long been known, and a considerable amount of geographic and geologic work has been done in it

[1] Van Hise, "Principles of North American Pre-Cambrian Geology," *U.S. Geol. Surv., Ann. Rept.*, XVI, 742.

by the earlier explorers, Richardson, Bell, Low, McOuat, and others. The results of this work, which was all of a reconnaissance nature, were published by the Geological Survey of Canada in 1903 as a map entitled "A Geological Map of the Basin of the Nottaway River," on a scale of ten miles to one inch. On this map, which has been out of print for some years, the rocks were subdivided into "Laurentian" and "Huronian." The former group included gneisses, granites, diorites and diabases; the latter schists, arkose, quartzite, etc.

The work done by M. E. Wilson, J. A. Bancroft, T. L. Tanton, and the writer has since the issue of the above-mentioned map resulted in a more precise mapping of the rocks of the region according to their age relations. These geologists have refrained from attempting the correlation of the formations described by them with formations outside the limits of the region and have used local names. It follows that there is at present no literature dealing with the correlation of this area with others. This paper is the first to deal with this problem, which is of a twofold nature. The first part, which can be dealt with with some degree of certainty, is the correlation of patches of formations of similar relationships within the region itself; the second part, on which the evidence is much more scanty, is the problem of correlating these formations with others beyond the limits of the region. In the latter regard there is some recent literature that has a direct bearing on the problems of this region.

The age relations of the Cobalt series of sediments have been recently established by W. H. Collins. He has traced these sediments from the Cobalt district to the original Huronian area on the north shore of Lake Huron and shown that there they overlie unconformably the Bruce series, which appears to be identical with the Lower Huronian of the Marquette district. As a tongue of the Cobalt series projects into the southwest corner of the northern Quebec area, where it overlies the older rocks with great unconformity, this determination of Collins is of the utmost importance in fixing the age of these older rocks.

Certain ancient sediments in Ontario have been described in recent years by Coleman, Miller, Collins, and others, under the local

names of Subdury series, Timiskaming series, and Hastings series. These may eventually be correlated, altogether or in part, with the Mattagami series of the region under discussion; but lack of knowledge makes this as yet no more than an interesting possibility.

The basal lavas of this region and of the Timiskaming district have almost universally been termed "Keewatin" by various writers, but there is little good evidence for so correlating them. Like the Keewatin of Lake Superior, they occupy a basal position in the geologic column, appear to be of pre-Huronian age, and are prevailingly basaltic and andesitic in composition; but more precise evidence of identity is lacking.

In connection with the occurrence in the northern Quebec region of a series of sediments which appear to be of Grenville age, a brief statement of the present status of the Grenville series is necessary. Rocks of the Grenville series were first described by Logan in 1847, and since that time he and many other workers have studied the series and extended our knowledge of it. A summary of the different investigations is given in Van Hise and Leith's "Pre-Cambrian Geology of North America."[1] The series has been definitely recognized only in eastern Ontario, Quebec, the Adirondacks, and the little-known area of Baffin Land; and singularly enough, in these areas other surficial formations of the pre-Cambrian are lacking, excepting the comparatively small development of the Hastings series, together with certain basic lavas. It was therefore impossible definitely to correlate the Grenville with any part of the pre-Cambrian developed in the region of the Great Lakes. Recognizing this, the International Committee in 1907 adopted the following simple succession for this region:

Cambrian: Potsdam sandstone, etc.
Unconformity
Pre-Cambrian: Grenville series
Intrusive contact
Laurentian

In the same year Miller and Knight, of the Ontario Bureau of Mines, published a brief description of work done by them in the

[1] *U.S. Geol. Surv., Bull. No. 360*, p. 448.

vicinity of Madoc, Ontario, contributory to the problem of correlation.[1] In this paper they state that in this district "an old greenstone series, with associated acidic, igneous rocks, similar to the Keewatin of the Lake Superior region, is widely developed. . . . . It has been proved by the writer that the Keewatin here is the oldest series in the region. The limestones are found to have been deposited on the surface of the Keewatin. An ancient Keewatin lava has, in places, been subjected to little denudation before the deposition of the Grenville limestone, which fills the cracks and openings in the ropy surface of the lava." This evidence, though interesting, is scarcely convincing, principally because it assumes that the basic lava apparently underlying the limestone is correlative with the Keewatin lavas of Lake Superior region. As basic lavas are found in the Lake Superior region, not only in the Keewatin, but throughout the whole pre-Cambrian, such an assumption cannot be accepted without proof. Exception might also be taken to the validity of the evidence advanced in regard to the relative ages of the lavas and the limestones. These rocks are all tilted into vertical attitudes; so that calcite might easily be carried by meteoric water from the limestone and deposited in cracks in the lava, even though such cracks were not formed till long after the folding was completed. Again, such cracks might have formed during the folding, and the limestone have flowed into them under the pressure of deforming forces. Either of these hypotheses would explain the presence of limestone in the cracks in the lava near the contact, regardless of whether the limestone had lain above or below the lava before deformation took place.

In 1914 Miller and Knight published a more extensive paper[2] on the relationships of the rocks of eastern Ontario. In this paper they still maintain the conformable relationships of the Grenville to the "Keewatin," but without adducing much new evidence. They describe in the Actinolite-Cloyne area a nuclear mass of greenstone surrounded by Grenville sediments. Regarding the relationships of the two, they state: "In the first place it is clear that the greenstone is not a deep-seated intrusive, or batholith,

[1] *Rept. Ont. Bur. of Mines*, 1907, Part 1, p. 221.

[2] *Ibid.*, 1914, p. 2.

invading the Grenville sediments. It is a volcanic or surface rock, retaining in places an ellipsoidal or pillow structure, and a fine or medium-grained texture. In the second place the greenstone does not send dykes into the sediments, nor give other evidence of being intrusive into these rocks. It is thus *inferred* that the quartzite, greywacke, and limestone are younger than the pillow lavas." Basing upon this evidence their conclusion that the "Keewatin" is older than the Grenville, they determine the Grenville to consist, from the base up, of gray gneisses and quartzites, some of which are garnetiferous, iron formation, and crystalline limestones.

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GENERAL GEOLOGY

The oldest rocks of the district are lavas, tuffs, and sediments. The bulk of the lavas are basalts and andesites, but more acid types, such as rhyolite porphyrites, are also present, though only in relatively small amount. Like the flows the tuffs vary in composition, and are of both coarse and fine grain. The flows and tuffs have been locally metamorphosed by dynamic or thermal agencies. They are probably to be correlated with the so-called "Keewatin" of Timiskaming district to the southwest; that they are of the same age as the Keewatin of the Lake Superior district has not yet been established.

The sediments associated with the volcanics are all more or less recrystallized and are now chiefly represented by garnetiferous and non-garnetiferous biotite gneisses, garnetiferous and non-garnetiferous hornblende gneisses, and crystalline limestones. These rocks probably are the metamorphic equivalents of impure sandstones, shales, and limestones. The original nature of the hornblende gneisses is not fully established, but from the entire absence of any evidence of igneous origin they are tentatively assumed to have been sediments. The clastic beds grade downward into beds of more tuffaceous composition, which lie conformably on the surface of the lavas. Evidence has been obtained that seems to indicate that these sediments, which have been termed the Nemenjish series, form the northern equivalent of the Grenville series of eastern Ontario and the Adirondacks.

In the vicinity of Lake St. John a granite is reported by J. A. Dresser to intrude the Grenville series and to be cut in turn by anorthosite. This granite has not been definitely shown to occur anywhere else throughout the region under discussion, but the reports of Adams, Cushing, and others suggest that it is found in areas to the east and south.

Younger than the granite just mentioned, and intrusive into it and the Grenville series, are great bodies of anorthosite and gabbro. Several of these are found in the area under discussion.

A few small patches of a younger sedimentary formation are found here and there throughout the region. These have hitherto been known by various local names, such as the Pontiac, Mattagami, and Broadback series. They include mainly conglomerate, arkose, and greywacke, and lie unconformably on all the older rocks, with the possible exception of the anorthosites. They are highly folded and metamorphosed, so that even the most competent of the rocks are converted into schists.

Following the deposition of these sediments came an intrusion of lamprophyre dykes. They are relatively few in number, but their distribution appears fairly general. Next in age are the enormous batholithic intrusions of granite, which now underlie about one-half of the region. It is possible that these may be of different ages, but no evidence of this has as yet been found. The intrusion of the batholiths probably followed closely the orogenic movements which folded the older rocks. They seem to have removed by stoping and digestion enormous thicknesses of the older rocks, including all of the ancient floor on which these were laid down, and undoubtedly also had a certain metamorphosing action on the adjacent rocks.

The Cobalt series, of Huronian age, rests with great unconformity on the surface of the complex described above. It is definitely recognized only in the southwest corner of the region, but a few small areas of similar rocks occur on Chibougamau Lake, and in the report of the Chibougamau Mining Commission were correlated with the Cobalt series.

Dykes of diabase petrographically similar to the Cobalt diabase cut the Cobalt series and all the older rocks. They are found sparsely distributed throughout the entire region. The diabase here never forms sills as in the flat-bedded rocks of the Cobalt region; hence the chance of mineralization by it is slight.

The youngest consolidated formation in the area is supposedly the flat-lying Mistassini limestone, which outcrops around Lake Mistassini and has been described by A. P. Low and the Chibouga-

mau Mining Commission. Because of its undeformed character and the presence of indistinct fossil-like forms, this formation has been placed tentatively in the late pre-Cambrian or early Paleozoic.

The geological succession, therefore, is as follows:

Mistassini limestones
Unconformity?
Diabase dykes
Cobalt series (includes Chibougamau formation?)
Great unconformity
Granite
Intrusive contact
Lamprophyre dykes
Intrusive contact
Sedimentary series (Pontiac series, Mattagami series, etc.)
Unconformity
Gabbro and anorthosite
Intrusive contact
Granite gneiss (around Lake St. John)
Intrusive contact
Nemenjish series
Abitibi volcanics (basalts, andesites, rhyolites)

METHODS OF DETERMINING STRUCTURE IN LAVA FLOWS

The lavas of the region afford exceptional opportunities for structural determination, since they have suffered relatively little deformation beyond a change in attitude. Each flow has moved as a unit during the folding, so that shearing has been confined to a marginal belt from one to ten feet in width. In the remaining portions of the flows the original structures and textures remain largely unchanged and can be used for determining the structure. The lack of deformation is undoubtedly due to the thickness of the flows, which has made them very competent to resist the deforming influences. The latter have been powerful enough to convert the conglomerate, arkose, and greywacke of the overlying Mattagami series into schist.

Grain and pillow or ellipsoidal structure were the structures and textures used in determining the attitude of the flows. Amygdaloidal textures, so frequently useful for the purpose, are not found here, since the margins of the flows are almost invariably schistose.

Pillow structure.—Pillow structure is well developed in the lavas over a large portion of the region, more particularly in the andesitic types, which commonly have large pillows from two to three feet in length. The basaltic lavas for some reason do not seem to form large pillows, the maximum observed being one foot in length; and on account of the blackness of the basalt it is more difficult to recognize and examine the pillows except on unusually clean, wave-washed surfaces.

A section made from top to bottom across an andesite flow about 130 feet thick on Windy Lake showed the following arrangement: At the top there is the usual narrow, schistose zone, below which there is a zone of pillows about 70 feet in width. At the top the pillows are from two to three feet in length; they gradually decrease in size, till near the middle of the flow they attain their minimum length of ten inches to one foot. Here the pillow structure ceases rather abruptly and passes into a fragmental zone about six feet in width. This is a true volcanic breccia, made up of fragments of fine-grained lava up to six inches in diameter imbedded in a matrix of lava of somewhat coarse grain. Some of these fragments are encircled by a whorl of lava about an inch in width, in which flow textures are prominent, as if the fragment had been revolving in the viscous lava. Below the zone of breccia, fine-grained massive lava occurs. The grain of this gradually increases in size as far as the bottom of the flow, where a grain of approximately 1 mm. is attained. This massive, relatively coarse-grained lava was observed in contact with the glassy, ellipsoidal surface of the adjacent underlying flow.

Only one perfect section across the whole width of a thick flow was observed, but a large number of partial sections were obtained, and the data are sufficient to show that the above represents the section wherever the flow is sufficiently thick to possess a massive base as well as a pillowed top. The succession described may therefore be used to indicate the position of the top of a tilted flow, even where only a part of the flow is visible. Of course this method is useless in flows pillowed throughout their entire thickness.

The method of determining the position of the upper surface of the flows from the flattening of the pillows, described by Daly,

Ransome, Russell, and M. E. Wilson, proved so difficult and uncertain of application that it was not used. That flattening is greater on the under side than on the upper was clear in most cases only when the position of the upper side had been previously determined by other means.

Grain.—A progressive increase in grain takes place in passing from the top of the flow toward its base. At the top the lava is

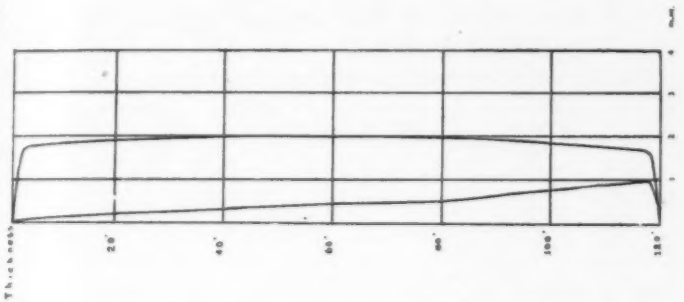

FIG. 2.—The curve to the left shows the change of grain in depth of a non-ellipsoidal andesite flow. The curve to the right is that for an intrusive of the same, thickness and composition. The maximum grain of the latter will of course vary, and may be much larger than represented.

almost or quite glassy, and the grain gradually increases in coarseness with depth till the maximum of approximately 1 mm. (in andesite) is attained a few inches from the bottom, where a narrow chilled edge is found. In the pillow lavas the fine, glassy grain persists throughout the whole thickness of the ellipsoidal zone. The curve in Fig. 2 shows the change in grain with depth of a non-ellipsoidal flow. For comparison the type of curve for an intrusive of the same composition and thickness is introduced.

It is obvious that if a sufficiently wide section can be obtained across the outcrop of a flow to show this change in grain the position of the top will be indicated. This, however, is only occasionally found possible in practice. The method is more applicable to the basaltic flows than the andesites, as their maximum grain is apt to be larger.

The methods of determining the positions of the upper surfaces of the lava flows may be summarized as follows:

A. In a single flow
   1. From changes in pillow structure with depth
   2. From changes of grain with depth

B. At contact of two flows
   1. From observation of a coarse-grained, non-ellipsoidal base resting on an ellipsoidal upper surface
   2. From observation of a coarse-grained base resting on a fine grained upper surface

The latter two methods are much the most useful.

[*To be continued*]

THE SALIENT FEATURES OF THE GEOLOGY OF OREGON.

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INTRODUCTION
PHYSIOGRAPHY
STRATIGRAPHY
- Pre-Cambrian
  - Archean
  - Algonkian
- Paleozoic
  - Devonian-Carboniferous
- Mesozoic
  - Triassic
  - Jurassic
  - Cretaceous
- Cenozoic
  - Eocene
  - Oligocene
  - Neocene
- Psychozoic
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GEOLOGIC HISTORY
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BIBLIOGRAPHY OF THE MORE IMPORTANT ARTICLES

INTRODUCTION

No article or book purporting to sum up the known geology of the whole of Oregon has yet been published. Even now the time has not arrived to essay anything like a complete story. Nevertheless it seems to be a propitious time to take an inventory of our knowledge. This seems desirable in that it will give those interested something like a connected account of the salient features, and on the other hand will afford the workers in the field a clearer idea of

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the problems involved. The writers are personally acquainted with much of the field and have made up for some of the deficiencies in their own knowledge by drawing upon the literature which they have deemed most reliable. In some cases, as will be indicated in the proper places, they have taken issue with earlier workers.

A few scattered references to the geology of Oregon in the earliest reports of various kinds are mainly of historic interest, but naturally at that time could not throw much light on problems of Oregon geology.

Dr. Thomas Condon, formerly a missionary, who came to Oregon in 1852, and who because of an unquenchable love and aptitude for natural history became a geologist, was the pioneer geologist of this state. His popular book on *Oregon Geology* and his collections, the first to be made in the now famous John Day basin, and the general stimulus he gave to later workers are his contributions, and no one has left a finer legacy to present-day workers.

In his published contributions Dr. Josiah Diller, veteran geologist of the United States Geological Survey, takes the lead. His work began in 1883 and he has since covered most of western Oregon. After Diller comes I. C. Russell, to whom we are indebted for much of our knowledge of southeastern Oregon.

The Oregon Bureau of Mines and Geology, created by legislative act in 1912, has contributed several important results of investigations, more especially relating to the economic aspect of the subject, and this Bureau has given financial assistance to other work which has not appeared in its publications. The Bureau maintains offices and a display collection of ores in Portland and issues monthly *The Mineral Resources of Oregon*.

The chief contribution to our knowledge of the Blue Mountain region of eastern Oregon has been made by Waldemar Lindgren.

Not the least important among the groups of investigators of Oregon geology is the department of paleontology of the University of California, which has devoted its attention largely to the fossil beds of eastern Oregon.

The University of Oregon, represented by a line of workers such as Ellen Condon McCornack, daughter of Dr. Condon, Chester

Washburne, Arthur J. Collier, Graham John Mitchell, and others, has contributed, if not voluminously, most substantially, to the accumulated knowledge in this field.

Besides those mentioned there are several other authors who have contributed one or more papers in special fields, and these are listed in the bibliography, which includes only the more important contributions to the subject.

PHYSIOGRAPHY

The state of Oregon is only a part of the older and much larger Oregon Territory. Its situation on the great western ocean is greatly in its favor, though it is less fortunately placed than either California or Washington.

Oregon is divided by the great Cascade Mountains into two very diverse regions, western and eastern Oregon, which differ radically, at least in the later periods, in physiography (including climate), geology, economic greogaphy, and also politically, socially, and in many other ways. Western Oregon is a marine province, and its geology in part is, in common with California and Washington, similar to that of Eastern Asia, while eastern Oregon is continental and belongs to the Great Basin province. A great portion of Oregon is covered by a part of the greatest lava flow in the world, and this has had a profound influence upon its history, both geologic and economic.

Following the Committee of the Association of American Geographers[1] there have been recognized the following physiographic divisions in Oregon:

1. "*The Oregon Coast Range* is the section of the Pacific Border Province west of the Puget Trough and consisting of Tertiary rocks," sandstones, and shales cut by igneous intrusives.

2. "*The Puget Trough*, the intermontane lowland west of the Middle and Northern Cascade Mountains." In Orgeon this is known as Willamette Valley and is filled largely with alluvium, but many outliers of Tertiary sediments and buttes with Tertiary igneous intrusives are found within this area.

3. "*The Middle Cascade Mountains* are that portion of the Sierra-Cascade Province whose height is due in part to volcanic

[1] *Ann. Assoc. Am. Geographers*, VI, 34.

accumulation and in part to crustal uplift." This is a great dissected plateau. Tertiary sediments in the form of a great synclinorium pass under these Tertiary and Pleistocene lavas.

4. "*The Klamath Mountains* are the section of the Pacific Border Province adjoining the Cascade Mountains on the west and consisting of relatively old and resistant rocks." The most noteworthy feature of this region is the remarkable peneplain described by Diller.

5. "*The Oregon Lake Section* of the Basin-and-Range Province characterized by young block mountains and lake basins."

6. "*The Harney Section* is that section of the Columbia Plateau which lies south of the Blue Mountains." This is largely underlaid by Columbia lava. It is characterized by sage brush, "rim rock," and lacustrine sediments.

7. "*The Payette Section* of the Columbia plateau is the part west of the Snake River Plain, whose substratum consists in large part of lacustrine sediments (applies to northern part only)." This takes in practically all of the upper Snake River drainage.

8. "*The Blue Mountain Section* of the Columbia Plateau Province is the mountainous area entirely surrounded by plateau surface." This section extends up into the northeastern part of the state and includes the Wallowa Mountains, which are in many ways quite different from the Blue Mountains proper. The writers are inclined to make a separate section for this portion.

9. "*The Walla Walla Plateau* is that section which lies north of the Blue Mountains."

This includes most of the DesChutes River basin and that of the famous John Day Valley. This region is noted for its fine wheat lands on the plateau stretches between the rivers and for the classic fossil localities along the John Day.

The writers suggest the following slightly simplified subdivisions:

a) The Columbia-DesChutes Province.
b) The Willamette Valley Province.
c) The Coast Province.
d) The Cascade Plateau Province.
e) The Klamath Province.
f) The Blue-Wallowa Mountain Province.
g) The Southeastern Desert Tract.

a) We think it inadvisable to run a physiographic boundary across a main stream like that of the DesChutes, and suggest that a heavy line (using the scheme of the Committee of American Geographers) instead of a broken line be passed around the *head* of this river. We think Columbia-DesChutes more appropriate than Walla Walla as a name for this province.

b) The writers are not yet ready to subscribe entirely to the inclusion of the Willamette Valley in the Puget Sound Trough and prefer the local name.

c) The Coast Province may be better than Coastal Range, since all of this province is not a mountain range.

d) Cascade Plateau Province we think is more fitting for this dissected plateau than "Cascade Mountains."

f) As the Wallowa, or Eagle Creek, Mountains, as they are sometimes called, are quite distinct in some ways, yet a part of the Blue Mountains, we suggest the name Blue-Wallowa Mountains.

g) We would include all the territory east of the Cascades and south of the Blue Mountains in one physiographic province. This includes territory with nearly similar geology and mainly without exterior drainage. There are differences here, of course, but we think not sufficiently great to warrant such division.

The hydrography of Oregon is interesting. The state is bounded by water on almost the entire distance of three of its sides; on the west by the Pacific Ocean; on the north by the master-stream, the Columbia; on the east for more than one-half the distance by the Snake. The northern and western portions are well drained by the following streams, respectively, the John Day and DesChutes; the Rogue, Umpqua, and Willamette. The major streams in general in Oregon are northward flowing. The southeastern lava plateau and desert region is a part of the Great Basin and therefore practically without exterior drainage.

The lakes of Oregon are especially interesting both for their variety and for their diverse origins. One of these is perhaps the most famous of all the lakes of North America, namely Crater Lake at the summit of the Cascade Mountains. We note the following types, which we can only name in passing in an article of this kind:

1. The coastal lakes—type, Tsiltcoos Lake.
2. The alkali lakes of the southeastern desert region—type, Harney Lake.
3. Crater lakes—type, Crater Lake.
4. Morainal lakes—type, Wallowa Lake.
5. Cirque lakes—type, Aneroid Lake.
6. Fault block depression lakes—type, Warner Lake.
7. Lava flow lakes—many in high Cascades.

STRATIGRAPHY

PRE-CAMBRIAN

Archean.—A biotite gneiss, imbedded in the granodiorite occurring along the headwaters of the north fork of John Day River is thought to be the oldest known rock of Oregon. This metamorphic rock outcrops on the north slope of Bald Mountain, covering an area of less than fifteen square miles. There is no reason given by Lindgren[1] why these rocks are considered as being pre-Cambrian. It is true that they are similar lithologically to gneisses in Calaveras County, California, and those near Shoup and Elk City, Idaho. Since metamorphics are products of dynamic conditions irrespective of time, there is no valid reason why gneisses and schists may not be found in later ages.

Algonkian.—Metamorphic rocks of supposed pre-Cambrian age also occur at or near the California-Oregon boundary. Schists are found near the headwaters of Wagner Creek west of Ashland, at Starling Peak still farther to the west, and thence westward along the boundary line to Takilma, interrupted, however, by smaller masses of Paleozoic metamorphics. These areas, excepting the first mentioned, extend into California in a southeasterly direction for a distance of many miles. These rocks are variously described by Diller,[2] Winchell,[3] and others as amphibolite, hornblendite, hornblende-mica, talc, and mica-quartz schists. Since they are either continuous with, or lithologically similar to, the beds across

[1] *U.S. Geol. Surv., 22d Ann. Rept.*, Part II, p. 594.

[2] J. S. Diller, *U.S. Geol. Surv., Bull. 546*, p. 14.

[3] A. N. Winchell, *Oregon Bureau of Mines and Geol., Vol.* I, No. 5, p. 37.

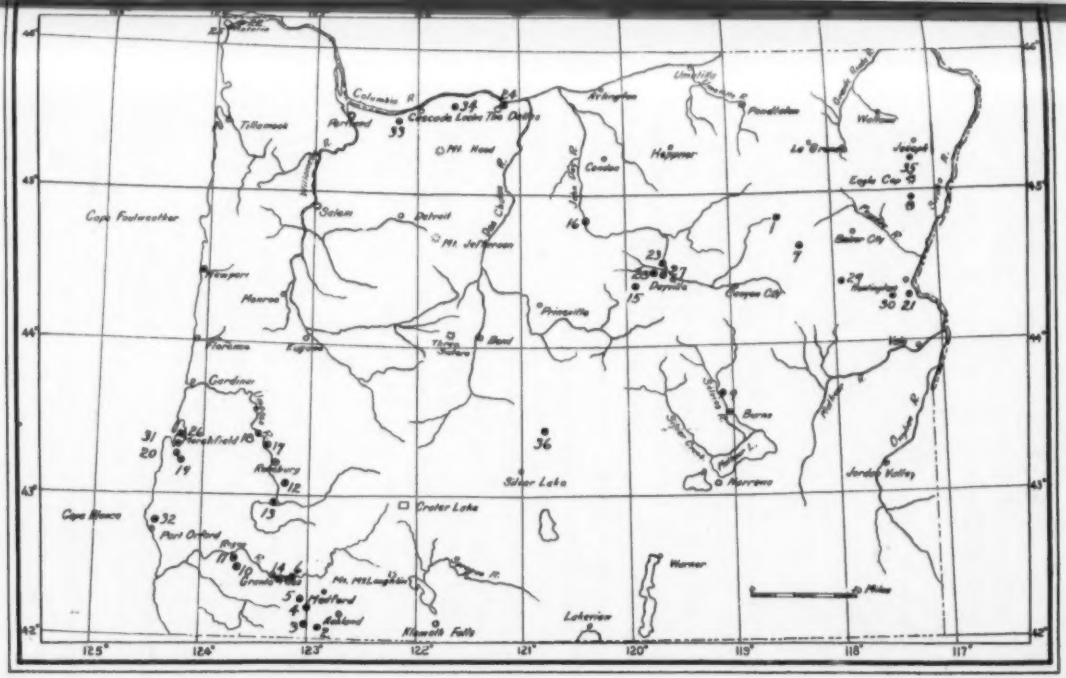

FIG. 1.—Formational locality map of Oregon: (1) Bald Mountain, Archean (?); (2) Abrams, Algonkian; (3) Salmon, Algonkian; (4) Little Applegate River, Devonian; (5) Kane Creek, Devonian; (6) Gold Hill, Carboniferous; (7) Winterville, Carboniferous; (8) Eagle Creek, Triassic; (9) Silvies River, Jurassic; (10) Galice, Jurassic; (11) Dothan, Jurassic; (12) Myrtle, Cretaceous; (13) Riddle Horsetown, Cretaceous; (14) '49 Mine, Chico, Cretaceous; (15) Spanish Gulch, Cretaceous; (16) Clarno Ferry, Eocene; (17) Umpqua River, Eocene; (18) Tyee, Eocene; (19) Pulaski, Eocene; (20) Coaledo, Eocene; (21) Payette, Eocene; (22) Astoria, Oligocene; (23) John Day, Oligocene; (24) Columbia Lava, Miocene; (25) Astoria, Miocene; (26) Empire, Pliocene; (27) Mascall, Miocene; (28) Rattlesnake, Pliocene; (29) Ironside, Pliocene; (30) Idaho Beds, Pliocene; (31) Coos conglomerate, Pliocene; (32) Elk River, Pleistocene; (33) Satsop, Pleistocene; (34) Cascade, Pleistocene; (35) Terminal moraine, Pleistocene; (36) Fossil Lake, Pleistocene.

the California boundary, which have been correlated with Hershey's,[1] Abrams, and Salmon series, it may be permissible to quote the description of the typical facies of those rocks as applicable in general to the Oregon beds:

> It [the Abrams mica schist] is composed of thin folia of muscovite of dull colors . . . . separated by irregular layers of white quartz representing the original laminae. Throughout it is very highly siliceous, and doubtless portions of it would by some be called micaceous quartz schist. In certain belts the silica predominates to such an extent as to cause it to outcrop like great veins of very glassy white and dark blue quartz.

This mica schist in California appears to grade upward through a graphite and actinolite schist to the hornblende schist series. These mica and hornblende schist series have an estimated thickness of 1,000 feet, which is no more than that developed by the first mentioned in the upper Coffee Creek section of northern California.

These old schists are in contact with the tonalite batholith at the California-Oregon boundary south of Ashland. This intrusive is of a much later date and possibly has been the dominant factor in the alteration of these sedimentary rocks to their present condition. Winchell states that these old beds are so intimately associated with intrusives as to make stratigraphic studies impossible in the vicinity of Red Mountain. The schistosity parallels the structure of the adjoining Paleozoic rocks, which have a general northeasterly strike.

Since these rocks, which were presumably originally argillaceous sandstones, or in places carbonaceous, as is testified by the graphitic schists, have been so completely metamorphosed their geologic age must be determined solely upon physical bases. The consensus of opinion seems to be that the schists at the state line are to be correlated with the Abrams and Salmon schist series of supposed Algonkian age.

PALEOZOIC

Devonian-Carboniferous.—During a part at least of the Paleozoic a sea covered a portion of eastern and southwestern Oregon. Although the Paleozoic rocks outcrop in both sections, the forma-

[1] O. Hershey, *Am. Geol.*, XXVII, 227.

tions have not been differentiated, and in both regions the stratigraphy is apparently hopelessly tangled.

In eastern Oregon Lindgren[1] found an argillite series with some limestone, which at Winterville contains crinoid stems, of probable Carboniferous age. Lindgren says of these:

> This argillite series is undoubtedly older than the Trias of the Eagle Creek Mountains, and may without much uncertainty be referred to the Paleozoic, possibly to the Carboniferous, which is so extensively developed in California. The whole argillite series, from Weatherby to the Greenhorn Mountains, is composed of fine-grained sediments, indicating deposition in deep waters. Sandstones, quartzites, and conglomerates are entirely absent, according to present information.

The structural features, according to Lindgren, verified to a limited extent in the field by the senior author, are quite irregular. They strike in the neighborhood of the Elkhorn Range a little north of west and dip 60 degrees south, but in the vicinity of Burnt River and Huntington they dip to the northward and strike southwesterly. No estimate of thickness of these formations, save that it may be several thousand feet, has been made.

In western Oregon there are, according to Diller[2] and Winchell,[3] about 10,000 feet of argillites, tuffs, and sandstones and limestone lenses of marine origin. This is indicated by the presence of siliceous beds containing Radiolaria.

As Winchell[4] has admirably summarized the information regarding these formations, we quote:

> The Paleozoic rocks are apparently structurally conformable both with older formations and with more recent beds, but there seems to be a hiatus in deposition both before and after the period. There is no unconformity known between the formations included in the Paleozoic. Like the Jurassic, the Paleozoic beds are nearly on edge, striking northeast and dipping steeply southeast. Elsewhere in this report the writer has suggested that these beds are all overturned, so that the Carboniferous beds are structurally beneath to the northwest, and the Devonian (and Silurian?) are above to the southeast.
>
> The classification of these Paleozoic rocks is based on fossils found in the limestone lenses, each of which has a maximum thickness of about 200 feet and a maximum length of about 2,000 feet. They have been assigned to four chief belts.

[1] W. Lindgren, *op. cit.*, II, 578.

[2] J. S. Diller, *op. cit.*, p. 15.

[3] A. N. Winchell, *op. cit.*, p. 35, p. 26.

[4] *Ibid.*, p. 26.

Beginning on the west the first belt includes lenses on Cheney Creek, others near Kerby, and some near Waldo. In this belt fossils collected by the writer have been considered to be probably Carboniferous in age by paleontologists of the U.S. Geological Survey.

The second belt includes outcrops southwest of Gold Hill, also some west of Provolt, those at Oregon Caves, and one on Sucker Creek. So far as known no fossils have been found in this group of outcrops.

The third belt comprises the lime quarries on Kane Creek, the outcrops near Applegate, and those west of Steamboat. Fossils obtained on Kane and Steamboat creeks consist merely of fragments of round crinoid stems.

The fourth belt of lenses is found in several outcrops on Little Applegate River (and across the divide on Anderson and Coleman creeks) and in one (or more) exposures near Watkins on Applegate River. In the former well-preserved round and pentagonal crinoid stems have been found. The fossils do not definitely determine the age of the third and fourth belts, and it seems possible that they should be referred to the Silurian, or an earlier period.

These limestone lenses are of considerable importance because limestone is so scarce in Oregon that the supply for cement and other uses must be sought in them or in similar outcrops. . . . . The origin of the limestone lenses is an unsolved problem of much interest and importance.

MESOZOIC

Triassic.—The Triassic is represented by sedimentaries and associated lavas reported by Lindgren[1] from the southern flank; and by Condon[2] from the northern flank of the Wallowa Mountains in northeastern Oregon. These beds are typically exposed along Hurricane Creek, Eagle Creek, and Powder River. The sedimentary members on Eagle Creek consist of calcareous shales, limestones, and agglomerates, aggregating several thousand feet. Nearer the batholitic core of the range they are altered to slates, schists and marbles. Farther west volcanic rocks, including basalts, andesites, and tuffs, comprise the dominant part of the series, while farther in the Wallowa Mountains masses of greenstone occur which may belong to this series.

J. P. Smith[3] records a section at Martin's Bridge on Eagle Creek consisting of fossiliferous shales and limestones. These are but little deformed. They yielded several species of *Halobia* and a number of corals, including *Montlivaultia* and the cephalopod *Dittmarites*. Condon obtained *Halobia rugosa* Guembel from the

[1] W. Lindgren, *op. cit.*, p. 580. [2] T. Condon, *Oregon Geology*, p. 48.
[3] J. P. Smith, *Am. Jour. of Sci.*, Series 4, XXXIII, 92–96.

north slope of the range, and W. D. Smith[1] notes fossils from near the summit of the range. These faunas are considered by J. P. Smith as representing a portion of the Hosselkus limestone of Karnic and Noric stages of Upper Triassic.

Jurassic.—This system is well developed in southwestern Oregon and is also known from the Blue Mountains. Recognizable Jurassic fossils were obtained by Condon[2] from Beaver Creek, a tributary of Silvies River, and from Red Butte, north of Burns. Nothing has been recorded regarding the extent or geologic relationships of these fossiliferous beds. Hyatt,[3] who examined the Condon collection, describes the matrix as a red sandstone. An examination of the specimens in the Condon Museum shows a fine-grained calcareous matrix, which is presumably an impure limestone.

The fauna includes *Peaten acutiplicatus* Meek, and *Pholadomya nevadana* Gabb as its most representative forms. These place the age of the beds as Lower Jurassic, of the Hargrave stage.

Diller[4] has shown the Jurassic rocks comprise the major portion of Oregon south and west of Rogue River. These rocks consist of sedimentary, metamorphic, and igneous rocks representing a wide range of rock types. The sedimentaries have been designated as the Galice and Dothan formations. Both formations are lithologically similar, and although now separated by a mass of greenstone and a zone of faulting the justification for separation into two formations has been questioned.[5]

The Galice formation outcrops as a band several miles in width extending northeasterly from the Oregon-California boundary. Northwest and roughly paralleling this is the type section some three miles wide and twenty to twenty-five miles long. The Dothan outcrops in a wide band still farther west and possibly extends northeasterly to the vicinity of Roseburg, Douglas County.

Both formations are composed of dark shales and slates, subordinate amounts of conglomerate, and lenses of red or gray chert. Both are steeply tilted, dipping generally to the southeast. The

[1] Smith, W. D. *Mazama*, Series 4, Dec. 1918, p. 238.

[2] C. Washburne, *Jour. Geol.*, IV (1906), 222.

[3] A. Hyatt, *Bull. Geol. Soc. Am.*, V, 401.

[4] J. Diller, *op. cit.*, Fig. 2.

[5] Winchell, *op. cit.*, I, No. 5, p. 35.

discordant dips support Diller's contention of distinct formations. Other field evidence indicates an overturning of these formations, making the Galice the older.

Marine invertebrate fossils from the Galice formation are the basis for the correlation of these beds with the Mariposa Jurassic of California. The fragmentary remains found in the Dothan resemble those from the Galice.

Franciscan Jurassic outcrops along the California-Oregon boundary for a distance of at least ten miles from the ocean shore. This region on the Oregon side, mapped as undifferentiated Jurassic by Diller,[1] undoubtedly contains Franciscan rocks. They also occur farther north in the Roseburg Quadrangle, where certain sedimentary and metamorphic rocks possibly once included within the Myrtle Cretaceous have been called the Dillard[2] and correlated upon their lithologic pecularities directly with the Franciscan. It is not improbable that these rocks connect with the Franciscan eighty-five miles farther south. Subsequent work by W. D. Smith[3] and by Davis[4] confirms the Franciscan age of these beds and adds weight to the prevailing opinion that these rocks are of Jurassic age, and that they are probably either younger or older than the Galice.

Igneous activity was pronounced during the middle Mesozoic. Various batholithic masses were intruded into the sedimentaries of British Columbia and the Coast states, resulting in regional metamorphism and often mineralization of earlier rocks, and either initiating or accompanying the uplift of the Sierras, Klamath, Blue, and Wallowa mountains.

In northeastern Oregon one or more granodiorite batholiths are now exposed as the cores of Wallowa and Blue mountains. Associated with these are diorites, gabbros, and peridotites cutting the pre-Cretaceous rocks of this region. The intrusion of the Siskiyou tonolite batholith was preceded by andesitic extrusives and intrusives, and basic rocks now largely altered to serpentines. These extensive intrusions of quartz diorite were later cut by dacite and aplite dikes. Although it is possible to determine the relative

[1] S. Diller, *op. cit.*, Fig. 2. [2] G. D. Louderback, *Jour. Geol.*, XIII, 528.

[3] W. D. Smith, *Am. Jour. Sci.*, XLII, 299.

[4] E. F. Davis, *Univ. Cal. Publ., Bull. Geol. Dept.*, II, 40.

age of these igneous rocks, their exact geologic age is unknown, they being presumably of late Jurassic age.

Cretaceous.—This system is developed along the southwestern flank of the Blue Mountains, eastern Oregon, and mainly within the valleys of the Rogue, Umpqua, and Coquille rivers of southwestern Oregon. The best-known localities within the former region are Mitchell[1] and the vicinity of Antone in Wheeler County. Broad exposures are found within the Port Orford, Coos Bay, and Roseburg quadrangles, and well-recognized areas in the vicinity of Riddle, Medford, and Ashland.[2]

These rocks in part represent the Shasta-Chico series of California yielding characteristic faunas and being lithologically similar to that series. The Shasta includes the Myrtle of Diller, whose most recent definition would include even the equivalent of the lowermost Knoxville as yet unknown in Oregon.[3]

The lower Myrtle, or the Knoxville of Oregon, as found in the above-named quadrangles, is composed of shales, sandstones, conglomerates, and lenses of limestones, all of which are in places locally metamorphosed and intruded by basic rocks. Dark-blue shales so typical of the Knoxville are known in several lower Myrtle areas in southwestern Oregon as well as at Mitchell in eastern Oregon. This latter locality has not as yet yielded determinable fossils, so its correlation with the Knoxville is only tentative. Heavy Myrtle conglomerates resting upon a basement complex representing successively higher horizons indicate a transgressing sea, which condition apparently continued until the close of the period.

The upper Myrtle, containing a Horsetown fauna, is well developed in the Myrtle Creek syncline of the Roseburg and Riddle quadrangles. It is not known to occur east of the Cascades. These rocks are somewhat more variable lithologically than the Knoxville, probably being more conglomeratic.

The Chico group along Rogue River consists of several thousand feet of sediments formed in a transgressing sea, which perhaps

[1] J. C. Merriam, *Univ. Cal. Publ. Bull. Dept. Geol.*, II, 280.

[2] F. M. Anderson, *Proc. Cal. Acad. Sci.*, Series 3, II, 1–154.

[3] B. Willis, *U.S. Geol. Surv., Prof. Paper No. 71*, p. 618.

extended eastward to the Blue Mountains, where the sediments now comprising the major portion of the Cretaceous outcrops were deposited.

The rocks of the Cretaceous system represent a presumably conformable series, which everywhere lies unconformably upon a complex of older beds. Tertiary strata generally are found to be markedly discordant with the Cretaceous. A long erosion interval appears to have followed the withdrawal of the Chico sea, during which time folding and intrusions occurred, followed by erosion which removed Cretaceous sediment of unknown extent.

The igneous rocks of the Cretaceous include gabbro, basalt, dacite-porphyry, and other rocks now altered to serpentine. These cut the Myrtle group in the order mentioned.

The Knoxville fauna is meager, including the boreal *Aucella piochii* (Gabb) and *A. crassicollis* Keyserling characterizing the lower and upper Knoxville respectively. The tropical Horsetown fauna from Riddle comprises about fifteen species, several of which are known from the California Chico. The Chico of Rogue River valley, at Mitchell, and near Antone in eastern Oregon have yielded a large fauna having local characteristics, yet being closely related to the Upper Cretaceous of California and having strong affinities with the Cretaceous of the Orient.[1] As yet no marine reptiles, so well represented in the interior sea to the eastward, have been discovered in the Pacific Coast province.

Four Pacific Coast Mesozoic floras, known as the Oroville, the Oregon, the Shasta, and the Chico, have been recognized by paleobotanists and have yielded evidence as to the age of certain beds which is difficult to reconcile with that afforded by the marine invertebrates. The oldest of these, the Oroville, is from California and is thought to be Middle Jurassic or pre-Maraposa. The Oregon flora is represented by the Thompson Creek, Douglas County, locality, and consists of over one hundred species, which show close affinities with the Oölite, Middle Jurassic, yet they appear to be associated with Knoxville invertebrates which paleontologists consider as belonging to Lower Cretaceous. The Shasta fauna from Elk River, Jackson County, is certainly associated with a

[1] F. M. Anderson, *op. cit.*, p. 62.

Knoxville fauna, including a number of well-known species. The latest, or Chico, flora is not well represented in Oregon but is in closer agreement with the invertebrate faunas.

CENOZOIC

Eocene.—Marine Eocene is known to comprise parts of the Coast Range[1] of Oregon from Rogue River northward to the Columbia, being well developed along their western flank within the Port Orford and Coos Bay quadrangles, and along their eastern flank within the Roseburg Quadrangle. These sediments outcrop along the western base of the Cascades east of Roseburg and at several localities within the Willamette Valley.

The Eocene rocks consist of sandstones, shales, carbonaceous shales and coals, conglomerates, tuffs, basalts, and various intrusives.

The Umpqua-Arago[2] group, including the marine and estuarine deposits, may represent over 20,000 feet of sediments, which are divided into a number of formations, the exact positions in the geologic column of several of which are as yet uncertain. The oldest, the Umpqua group, is well developed on Little River, Roseburg Quadrangle, where it consists of 7,500 feet of marine sediments. This group includes the Wilbur tuff—lentils, the Umpqua formation, the Tyee sandstone, and possibly the Oakland limestone formations. The most important of these is a rather coarse-grained, thick-bedded sandstone known as the Tyee sandstone. This has been traced by Washburne[3] from Rogue River Mountain northward along the Coast Ranges into Tillamook County.

The Arago, the lower part of which may be the equivalent of a part of the Umpqua formation and the later Tyee sandstone,[4] is found within the coast quadrangles and consists mainly of sandstones and shales, some of which are coal-bearing. The older Pulaski formation also includes some fossiliferous limestone and basaltic tuffs. The younger Coaledo formation is coal-bearing, but along the eastern margin of the field includes some basaltic

[1] S. Diller, *U.S. Geol. Surv., 17th Ann. Rept.*, Part I, p. 469.

[2] *Ibid.*, Folios 49, 73, and 89.

[3] C. W. Washburne, *U.S. Geol. Surv., Bull. 590*, p. 9.

[4] R. E. Dickerson, *Proc. Cal. Acad. Sci.*, Series 4, IV, 114.

flows and diabase. Probable equivalents of the upper portion of this series are found in the Ione lacustrine deposits within the Rogue River valley.

The Eocene beds have been thrown into gentle folds, which even along the crest of the Coast Range are nowhere as steep as those developed in the Myrtle or older beds. In places normal faults have developed, the thrust fault being less frequently seen.

Eocene invertebrates occur at a number of localities. These are typical Tejon forms, including the well-known *Turritella uvasana* Gabb and *Venericardia planicosta merriami* Dickerson. The large fauna from the Little River, Roseburg Quadrangle, as shown by Dickerson, belongs to the Siphonalia sutterenses zone of upper Tejon. Since this was found some 10,000 feet from the base of the Umpqua-Arago series, and since the Arago of Diller has been by several considered later than the Umpqua formation, it may prove to be the brackish water equivalent of the Ione Eocene of California.

With the beginning of the Eocene eastern Oregon became a province, distinct both geologically and physiographically. The oldest Tertiary beds have been described as the Clarno by Merriam,[1] and named after the type locality, Clarno Ferry, Wheeler County. The formation was also recognized in the vicinity of Fossil and along the west side of John Day River, and was later extended eastward to Heppner,[2] as a strip ten to fifteen miles wide.

The Clarno is typically composed of varicolored sandstones and shales, which are in places carboniferous, grading upward into paper shales and coarse rhyolitic tuffs. In places near the bottom andesitic flows are found, while rhyolites occur nearer the top of the section.

These beds range from 400 to 2,000 feet in thickness. They have dips as high as 25 degrees, which may be locally increased upon fault blocks. The Clarno rests unconformably upon Chico Cretaceous at Mitchell and upon the Knoxville (?) shales farther west. An angular unconformity with the overlying John Day beds

[1] J. C. Merriam, *op. cit.*, II, 285.

[2] W. G. Mendenhall, *U.S. Geol. Surv., Bull. 341*, p. 406.

has yet to be reported. It is, however, presumed that a hiatus between the two will be found.

These terrestrial beds have yielded fossil plants only, which were early discovered at Bridge Creek by Condon. The flora, as determined by Knowlton, comprises about twenty-five forms, which indicate the Eocene age of the formation. There is some evidence that both the lower and upper Eocene floras are represented.

In Malheur and Harney counties a series of sedimentary beds occupies, in part, the Snake River Valley from a point near Owyhee northward to Ontario, extending westward to a locality some thirty miles southwest of Vale.

These beds consist mainly of unconsolidated gravels, sands, clays, and volcanic ash. Similar beds along Snake River in Idaho have been described by Lindgren[1] as the Payette formation. He ascribes their origin to a large Neocene lake, but Russell[2] inclined to the belief that the Oregon beds were of fluvatile origin. These may well include other Tertiary strata, as Washburne[3] suggests, and as is apparently proved by Merriam[4] by the discovery of the Ironside formation at Ironside. The fossil leaves and fresh-water mollusks indicate an early Tertiary age for these beds. The Payette has been correlated with the Ione, Upper Eocene of California, upon the basis of fossil plants, and with the Upper Clarno of the John Day Valley by Merriam. If it is the equivalent of the Upper Clarno the sedimentation was much more rapid in the Payette Basin.

Oligocene.—Certain marine beds at Astoria, well known through the early work of Dana, Conrad, and Condon, were the first of the entire coast to be assigned to the Oligocene. The basis upon which the correlation was first made by Dall has not as yet been discussed. This Astoria section now serves as the type section for the west-coast Oligocene, which is now known to be well developed in the adjoining states.

In Oregon, Oligocene faunas have been identified by Clark[5] and others from a number of localities, mainly in Clatsop, Columbia,

[1] W. Lindgren, *U.S. Geol. Surv.*, Folio 103, p. 2.

[2] I. C. Russell, *ibid.*, *Bull. 252*, p. 31.

[3] C. Washburne, *ibid.*, *Bull. 431*, p. 27.

[4] J. C. Merriam, *op. cit.*, X, 111.

[5] B. L. Clark, *Univ. Cal. Publ., Bull. Dept. Geol.*, II, 102.

and Tillamook counties, and at Eugene, Lane County. These and other less well-known localities indicate that the Oligocene is quite extensively developed throughout northwestern Oregon, eastward to the foothills of the Cascades, and at least as far south as Eugene. Much remains to be done in connecting, or correlating, these rather isolated areas.

These Oligocene strata, aggregating several hundred feet, consist of marine shales, sandstones, conglomerates, tuffs, and basaltic intrusives, varying considerably in character from locality to locality.

The Oligocene marine fauna of Oregon is but imperfectly known, the *Molopophorous lincolnensis* and the *Acila gettysburgensis* zones of Washington being certainly recognized.

The upper Oligocene is well developed within the John Day Valley, where some 1,500 feet of sedimentaries are known as the John Day series. It is well exposed along the valleys of the John Day from Picture Gorge to Clarno, and along the North Fork to a point some distance above Monument. Other isolated localities are known outside the John Day drainage basin. The series is divisible into three lithologic and paleontologic divisions, the lower of which is characteristically composed of red, green, or white shales; the middle division by drab and bluish tuffs; and the upper by buff tuffs, rhyolite, sands, and gravels. These terrestrial beds are but little deformed, dips of 5 to 10 degrees being rather exceptional.

The remarkable vertebrate fauna is confined to the two upper divisions, the middle yielding a *Diceratherium* zone fauna of over fifty species. The upper fauna is that of the *Promerycochoerus* zone. This John Day fauna of over one hundred species is correlated with the upper portion of the White River group.

Neocene.—The Neocene of western Oregon is represented by a series of sedimentaries yielding a lower or Monterey fauna, and an upper or Empire-Merced fauna. The beds yielding the Monterey fauna have not as yet been clearly differentiated from the Astoria group, so that their distribution and geologic characteristics can be given only in the most general terms. They include, in part, the "Solon Beds" of Condon. The strata at these localities con-

sist of marine sandstones and shales of as yet an undetermined thickness.

An invertebrate Monterey fauna is reported by Arnold and Hannibal[1] from Astoria, Mountain Dale, Westpoint, Tillimook, and along the ocean shore in the vicinity of Newport. Much, if not all, of the reported Miocene in the Coast Ranges and the Willamette Valley is now assigned to the Oligocene. A fauna of over thirty species has been obtained by Hannibal at Astoria, including *Arca devincta* Conrad, *Pecten propatulus* Conrad, *Turritella oregonensis* Conrad. These are thought by him to be characteristic of the Monterey of California, which is of lower Miocene age. Marine vertebrates, including *Desmostylus hesperus* Marsh, and *Desmatophoca oregonensis* Condon, have been found in these beds in the vicinity of Newport. These important fossils point to a middle Tertiary age of these beds.

The upper Neocene beds were described by Diller[2] as the Empire and assigned to the Miocene. They are known from the Coos Bay and Port Orford quadrangles, where they consist of light-colored shales and sandstones, which are in places massive. These rocks, aggregating about five hundred feet in thickness, lie unconformably upon the folded edges of the Eocene sediments, and in turn are disconformable with the overlying Pleistocene deposits.

Dall's[3] list of 90 species of marine vertebrates from the Empire has been considerably extended by subsequent workers. This formation until recently considered of Miocene age is now thought to belong to the early Pliocene.[4]

Unconformably overlying the Empire beds at Fossil Point, Coos Bay, is a mass of heavy conglomerates known as the Coos conglomerates, some thirty feet in thickness, which has yielded a small marine fauna, considered Pleistocene by Dall,[5] but Pliocene by several other workers.

Terrestrial beds discovered by LeConte and more recently described by Williams[6] as the Eagle Creek formation occur at or near

[1] R. Arnold and H. Hannibal, *Proc. Am. Phil. Soc.*, LII, 576.
[2] J. Diller, *U.S. Geol. Surv., 17th Ann. Rept.*, Part I, p. 475.
[3] W. H. Dall, *U.S. Geol. Surv., Prof. Paper 59*, p. 18.
[4] B. L. Clark, and R. Arnold, *Bull. Geol. Soc. Am.*, XXIX, 298.
[5] W. H. Dall, *op. cit.*, p. 19.
[6] I. A. Williams, *Mineral Resources of Oregon, Oregon State Min. Bur.*, II, 80.

the base of the Columbia lavas at Eagle Creek, Multnomah County. This formation consists of hardened ashy clay and has yielded a flora of over forty species, which is thought to be of upper Miocene age. Such a determination would place the Columbia lava in the late Miocene, or Pliocene, which is contrary to the evidence afforded by the Mascall fauna, which occurs within the John Day Valley and has yielded an extensive middle Miocene fauna.

Unfortunately this name is preoccupied by the Triassic Eagle Creek beds of the Wallowa Mountains. The Miocene formation might well be called the Warrendale formation, from the town of that name, near Eagle Creek, a tributary of the Columbia.

W. D. Smith[1] has described a series of at least four hundred feet of buff-colored tuffs occurring on the Santiam River near Cascadia, which may be correlated with the Warrendale formation, or possibly with the John Day. As yet no fossil remains have been found in these tuffs.

Lying above the Warrendale formation, which may later prove but a local interbedded deposit, is the Columbia lava, a name applied by Russell to basaltic flows occurring extensively in eastern Washington and redefined by Merriam[2] to include only the lavas younger than the John Day Oligocene and older than the Mascall middle Miocene. As thus defined the Columbia lava is a widespread formation covering large areas in eastern Oregon, eastern Washington, western Idaho, and northern California, entering into the structure of the Oregon Cascades as shown by Diller, Williams, and Smith, and occurring presumably in discontinuous areas of western Oregon.

The Columbia lava series consists of basaltic flows, often interbedded with lateritic deposits and tuffs. These vary considerably from place to place as regards number and thickness. Twenty-three have been counted on the John Day and twenty in the Columbia gorge.

East of the Cascades these flows are often but comparatively little deformed, though in places they have been faulted, resulting in the typical block-fault type of mountains. In some places this

[1] W. D. Smith, *Univ. of Oregon Bull. 16*, p. 38.

[2] J. C. Merriam, *op. cit.*, II, 304.

apparent folding may be due to pre-existing irregular topography. Along the Columbia River gorge the flows are seen to be thrown into an anticlinorium.

The age of this series of flows is definitely limited by the middle Miocene Mascall and the John Day Oligocene.

Beds unconformably overlying the Columbia lava within the John Day Valley have been named the Mascall formation.[1] These beds, aggregating about one thousand feet, consist of conglomerate, sand, ash, and tuff, and have yielded a rich vertebrate fauna and a well-defined flora,[2] of middle Miocene age.

The Pliocene of eastern Oregon is represented by the Rattlesnake,[3] Ironsides, and Idaho beds. The oldest of these, the Rattlesnake, is typically developed on Rattlesnake Creek, near the Mascall Ranch on John Day River. These beds have been recognized by Osmont in the Crooked River Valley. The Rattlesnake consists of coarse basal gravels, brown tuff, and a rhyolite flow. This formation has been deformed and in places faulted. Its vertebrate fauna, though meager, is sufficient to indicate an early Pliocene age.

Sedimentary beds at Ironside,[4] Malheur County, have recently been designated the Ironside formation. Buff-colored, sandy shales and shales of possibly two hundred feet in thickness, now deformed, yielded a small vertebrate fauna which Merriam considers as being younger than the Rattlesnake Pliocene.

Lindgren[5] has described certain lacustrine deposits along Snake River as the Idaho formation. This has not been distinctly separated structurally and lithologically from the earlier beds of the same region known as the Payette, though the presence of equine and proboscidian remains prove the presence of later beds.

PSYCHOZOIC

Pleistocene.—The Pleistocene of Oregon includes lake, glacial, and river deposits, marine conglomerates, sands, peat, and extensive igneous formations. It is yet too early to put all these widely

[1] J. C. Merriam, *op. cit.*, II, 305.

[2] F. H. Knowlton, *U.S. Geol. Surv., Bull. 204*, 1902.

[3] *Op. cit.*, p. 310.

[4] J. C. Merriam, *op. cit.*, X, 129.

[5] W. Lindgren, *U.S. Geol. Surv.*, Folio 103, p. 2.

separated and heterogeneous materials in their proper chronological order.

At many points along the Oregon coast, but especially well developed at Cape Blanco, we find marine conglomerates, sands, and shell beds lying unconformably above the Empire (Pliocene) and nearly horizontal, but with a slight southerly dip. The section at Cape Blanco is described and figured by Diller.[1]

There are two distinct horizons above the Empire here, the lower one being presumably the Cape Blanco beds of Diller which Dall has suggested may correspond to the Merced of California and hence Pliocene. The upper part with recent-looking shells is Pleistocene, without much doubt. These have been called the Elk River beds, which Arnold and Hannibal[2] correlate with the Saanich formation of Puget Sound. These investigators do not appear to make any separation of the beds overlying the Empire.

Diller notes a lithologic difference between the Blanco and the Elk River beds, chiefly in the matter of consistency. This may be of little significance. Similar Pleistocene marine deposits can be seen in similar position all along the Oregon coast to the Columbia River.

From a consideration of the above-mentioned deposits we are led to discuss the Satsop formation of Bretz,[3] in which this investigator includes some at least of these coastal gravels. His type locality for this formation is in the Chehalis Valley, Washington, and the formation is especially well represented in Oregon along the Sandy, a tributary of the Columbia River, near Portland. Bretz's description of this formation along the Sandy is as follows:

> The formation is at least 600 feet thick along the Sandy River, with the base below river-level. The material is stream-bedded gravel and sand, indurated in some places to a conglomerate and sandstone. Quartzite is a common constituent for 10 miles south of the Columbia, but has not been found more than 15 miles from the master-stream. Quartzite and basalt are the most important constituents.
>
> The Satsop formation of the lower Willamette Valley is maturely dissected, the dissection adjusted to a base-level 200 feet or more above present flood

[1] J. S. Diller, *U. S. Geol. Surv., Bull. 196*, p. 31.

[2] R. Arnold and H. Hannibal, *op. cit.*, LII, 508.

[3] J H. Bretz, *Jour. Geol.*, XXV, No. 5 (1917), 446–59.

plains. This level is recorded in the major valleys by a prominent terrace developed mostly in the Satsop formation but in places cut in the underlying basalt. This is the Cowlitz Terrace already described.

The uplands of this Satsop plain bear a red clay soil 10–15 feet deep. This grades down into a much-decomposed gravel. At a depth of 30 feet the pebbles are decayed only on the exterior. Below 50 feet most of the material is hard and ringing when struck with the hammer. Near the Columbia the clayey residual soil on the top of the Satsop formation contains scattered quartzite pebbles, hard, bright, polished, and apparently unaffected by the weathering which has reduced the associated basaltic pebbles to a structureless clay.

The present writers have examined this formation along the Sandy and the Columbia rivers near Crown Point, but have not traced it over anything like the territory covered by Bretz. Wherever they have seen it the formation appeared to be an ordinary river gravel plastered against the sides of the valleys and on benches above the present stream beds. We did not see it disappear under the andesitic lavas at any point, though we are not prepared to say that is may not do so. A deposit of gravel might very easily be laid down underneath an undercut cliff and in this way give one the impression of having been laid down first, with a lava flow rolling out on top of it later.

With these river gravels Bretz correlates, by taking a long jump, the gravels already referred to, occurring at Cape Blanco and Elk River. He also suggests the inclusion of the quartzitic gravels in eastern Oregon at The Dalles. Why not go farther east to the John Day country, where the Rattlesnake formation (Pliocene) is found to contain many quartzitic pebbles! As yet no fauna has been found in these Cascade gravels.

Fossil leaves were found in this formation by J. B. Winstanley, of Portland, and collections were made by R. W. Chaney, of the University of Chicago. Of these I. Williams,[1] in his Columbia Gorge paper, says:

The fossil horizon is exposed three-fourths of a mile back from the Sandy River road, in the south side of the canyon of Buck Creek 25 feet above the water, beneath an overhanging cliff of conglomeratic phase in which pebbles of polished quartzite are common. Mr. Chaney states that in this one exposure of the Satsop, four genera and at least seven species of plant life are represented.

[1] I. Williams, *Ore. Bur. Mines and Geol.*, II, No. 3

They include the oak, willow, walnut, and the sequoia. The latter is apparently the living redwood of California. Both the oak and the willow likewise closely resemble their living relatives in that sister-state at the south.

There are in this Satsop flora above the Columbia basalt remains of several of the same genera found in the Eagle Creek strata below that great body of lava, but their specific characters are so markedly more modern as to brand this flora at once as belonging to a distinctly later age. On the other hand, this flora includes plants that at present grow upon the earth, most of them, however, flourishing only in the warmer climate of lower latitudes. Such equivalence to living forms might imply enforced migration, the retrieval of lost territory having not yet, to the present, been made. Or more likely, that the climate in which they grew, and prior to their displacement, was a more equable one than ours of today. In any case, similarity with land plants found elsewhere in undoubted Pleistocene strata, as well as with those of the present, affords us tentative grounds at least for saying with added confidence that the Satsop formation, as it enters into the structure of the Cascade Range, appears to belong to the Pleistocene.

The deposits at Fossil Lake and at other lakes of the semiarid region of south-central Oregon are definitely referred to the Pleistocene. First it should be stated that the avifauna and equifauna mentioned in the literature in connection with Silver Lake came from Fossil Lake a few miles northeast of Silver Lake. As there are two Silver Lakes in south-central Oregon, the name Fossil Lake ought to be used to the exclusion of that of Silver Lake.

This lake is now dried up, and the surface material consists of a light-colored mixture of sand, clay, and silts. Some of this may be a fine-grained tuff. Deposits of tufa, or lime carbonate, are found covering much of the surface about these lakes.

We cannot refer these deposits to their proper zone at the present time. In these same beds containing Pleistocene animals there were some human artifacts, chiefly arrowheads, which it is thought are of more recent origin.

Extensive and highly important collections, principally of birds and horses, have been made here by various institutions, Dr. Thomas Condon being the first scientist to explore them. The most notable studies made on this subject are by Schufeldt[1] and by Cope.[2] Many bones of the mammoth, of camels, and horses

[1] R. W. Schufeldt, *Jour. Acad. Nat Sci.*, Philadelphia (1892), No. 9.

[2] E. D. Cope, *Am. Natural.*, XXXIII, 970-82.

(*E. pacificus*) from this locality are in the Condon Museum at the University of Oregon. A flamingo is perhaps the most striking feature of this fauna. Schufeldt thought that these deposits were of Pliocene age, but Osburn and others have shown that they must be early Pleistocene.

Above the Columbia lava and the Satsop is the great pile of more recent lavas in the Cascade Range which have been found to be predominantly andesitic. A part of this series of several thousand feet of thickness is undoubtedly Pleistocene, but the lowest portion may be Pliocene and the upper portion may be Recent. These lavas make up the bulk of the several more or less eroded cones, such as Hood, Jefferson, Three Sisters, and McLoughlin, which rest upon the Cascade basaltic lava plateau.

No comprehensive article or book has been devoted to the subject of glaciation in Oregon, and very few papers of any kind have discussed it. On the highest mountains in the state, in the Wallowa Mountains and the Cascades, there are mere remnants of one-time large glaciers, and these are relatively unimportant. We have never seen a catalogue of the glaciers in Oregon and do not know exactly how many there are. In the Wallowa Mountains there is only one glacier of any consequence, and it is not large. On Mount Hood there are eight, on Jefferson four, and on Three Sisters eleven. How many there are on Mount Washington is not known. Mount McLoughlin is too far south, we believe, and not of sufficient height to have much ice upon it.

Though the existing glaciers are small in Oregon (the largest, Collier Glacier on the Sisters, being not over a mile in length) they were once much more extensive, for their despoits are found at much lower elevations.

Every class of glacial deposit characteristic of alpine glaciers can be found within the limits of the state. The largest moraine the writers have seen is the lateral moraine on the east side of Wallowa Lake in the extreme northeastern part of the state. This is about six miles long, one-fourth of a mile wide, and between six and seven hundred feet high. It is fivefold at its lower end.

Perhaps the most interesting and at the same time most puzzling phenomenon connected with the subject of glaciation in Oregon is

the erratics of granite, quartzite, and argillite to be found here and there in the Willamette and adjacent valleys in western Oregon. One of these erratics is a polished and striated quartzite bowlder about the size of one's head. The striations are unmistakably of glacial origin. Their presence has been explained, perhaps correctly, by Condon as having been dropped from icebergs floating in the "Willamette Sound." It is difficult to explain the presence of these on any other basis, as they could hardly have been brought down from the upper Willamette Valley, since no such rocks have yet been found near the headwaters of that system of drainage. However, all these rocks are found in eastern Oregon, whence they might have been transported by the Columbia.

There was undoubtedly a large body of water occupying at least the lower portion of the Willamette Valley, but this, as both Dr. Condon and his daughter, Mrs. McCornack, expressly stipulate, was in part fresh. Thus the use of the term "sound" is perhaps unfortunate. The flatness of the floor of the Willamette Valley has been attributed to the presence of this sound, but is more easily explained by aggradation and the lateral planation by the river.

A fauna from scattered localities within the Willamette Valley has been reported by Mrs. McCornack.[1] The interpretation of this fauna, which includes a horse, a bison, a mammoth, and a camel, may have an important bearing upon the "Willamette Sound" and the "Satsop" problems.

Recent.—Among the forms of deposits and events of the Recent period in Oregon we may note the following:

1. Gravels—stream, ocean littoral.
2. Talus—on the valley sides.
3. Dunes along the coast and in lake region of eastern Oregon.
4. Peat bogs in the coastal dune area.
5. Volcanic deposits in the Cascades.
6. Shore deposits, beaches, bars.

This list does not pretend to give the chronological sequence, about which there is more or less conjecture. Some of these undoubtedly are synchronous. About the first two little need be said, as these are found everywhere.

[1] Ellen Condon McCornack, *Univ. Ore. Bull.*, XII, No. 2 (1914), 13.

System	Group or Series	Formation	Section	Lithology	Correlatives
Recent		Alluvium		6'/85 Sands and gravels	
		Volcanics		6'/43 Rhyolitic flows, pyroclastics	
Pleistocene		Terrace		60-85 Sands and gravels	Sedgwick
		Elk River		80-120 Shales, sands and gravels	San Pedro (?)
Pliocene	Merced	Coos Conglomerate		6'0039 Conglomerate	
		Empire		6'0039 Sandstone and shales	Merced
Miocene Lower	Monterey	"Salem Beds" in part		3'9308 Shales, sandstones, basaltic flows (?)	Monterey
Oligocene	Astoria			3'1408 Shales, tuffaceous shales, and basaltic intrusives	San Lorenzo (Clark)
Eocene Upper	Arago-Umpqua group	Coaledo, Flaherty, Tyee sandstone, Umpqua and Walker formations		36000' Sandstones and light colored coal seams. Sandstones, shales, basaltic intrusions. Impure limestone, massive mesaceous sandstones and shales, andesitic intrusions. Conglomerates, sandstones, shales, limestone lenses, tuffs, and intrusions of diabase.	Juna. Tapa.
Upper	Chico	Chico		10000' Sandstones and shales with interbedded conglomerates, intrusions of serpentine and gabbro cutting the Cretaceous rocks.	Chico
Cretaceous Lower	Myrtle	Horsetown		20000' Conglomerates, sandstones, and sandy shales.	Horsetown
		Knoxville		Dark shales, thin bedded sandstones and conglomerates.	Knoxville
Jurassic	Dothan			31000' Granodiorite batholiths, argillite, shale, sandstone, radiolarian cherts, intrusives, andesites, and serpentines.	Franciscan (?)
	Galice			15000' Argillites, shale, sandstone	Mariposa
Carboniferous		Wolde-Rocky Point Gold Hill-Oregon Cove beds		11000' Argillites, sandstones, cherts, limestones.	
Devonian		Applegate-Nora Creek beds Little Applegate-River beds		Tuffs, andesitic flows and intrusives.	
Algonkian (?)		Salmon		1000' Hornblende schists	Calaveras schists (?)
		Abrams		500' Mica schists	

GEOLOGIC COLUMN OF WESTERN OREGON

Syst
Recent
Pleistoce
Pliocene
Miocene
Oligocen
Eocene
Cretace
Jurassi
Triassic
Carbon
Archea

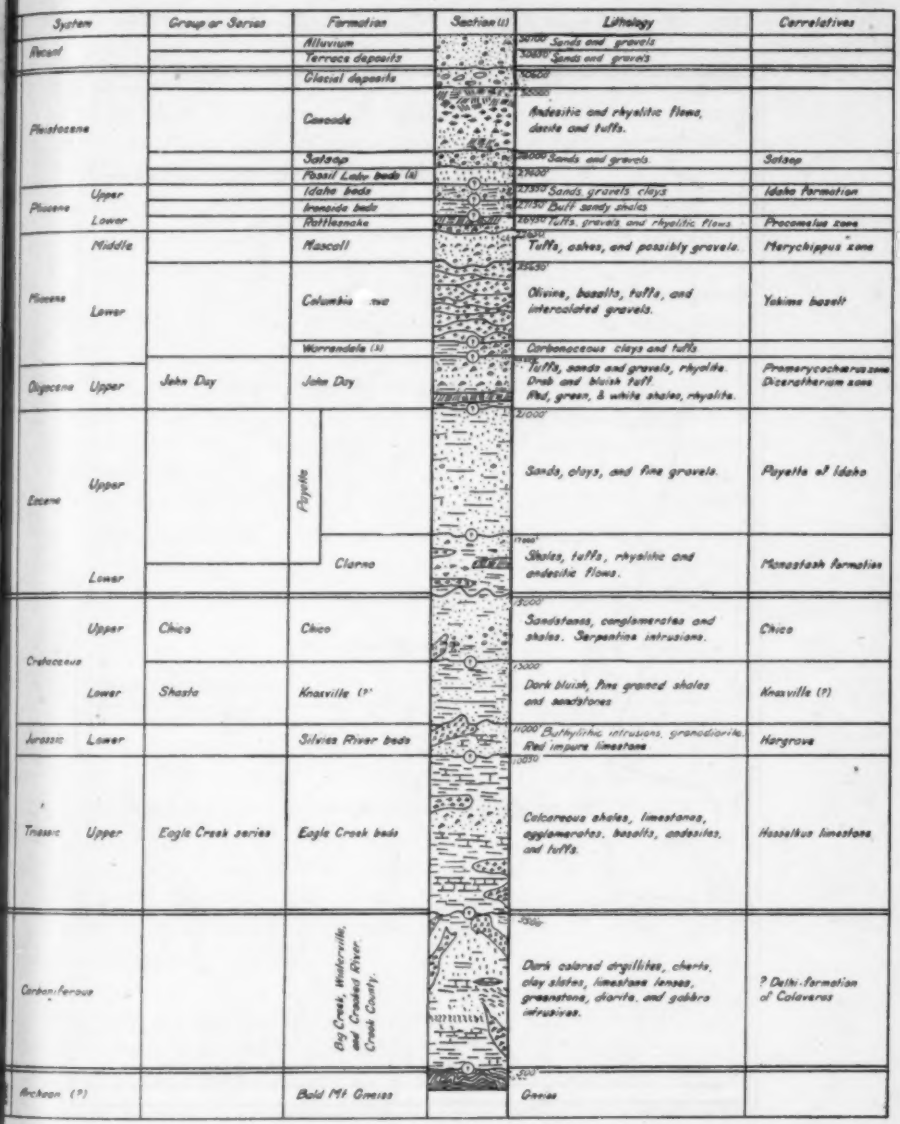

FIG. 2.—Geologic column of eastern Oregon

(1) These thicknesses are in most cases only approximations.

(2) The relationship to the Satsop is unknown.

(3) The relationship to the John Day is unknown.

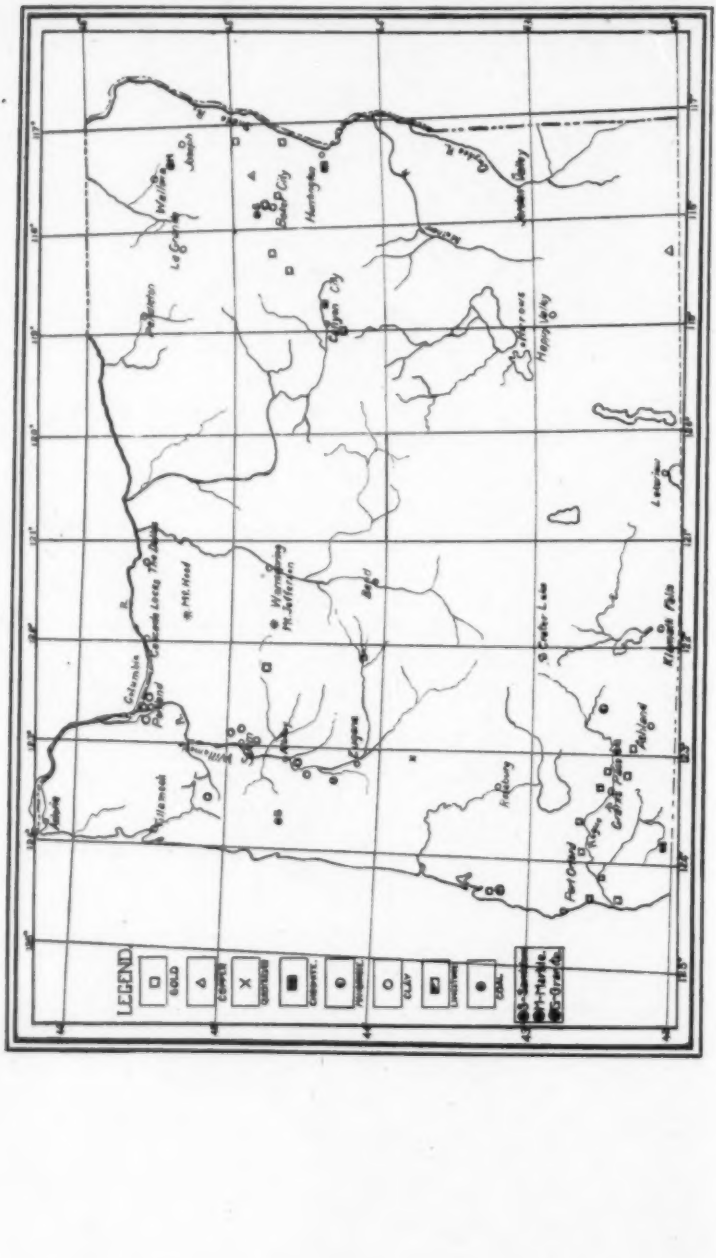

FIG. 3.—Principal mineral localities in Oregon

In the topography of the Oregon coast dunes are especially noteworthy, since Neocene and Pleistocene sandy formations outcrop throughout practically its whole length. These shifting sands have, besides resulting in dunes, caused the formation of a chain of very interesting and picturesque lakes. These lakes owe their existence to the damming up of sluggish streams by the shifting ocean sands.

Peat bogs are now forming in these dune areas, where large quantities of sphagnum moss and rhododendron leaves accumulate. In the cliffs overlooking the sea, near the top of the section in many places can be seen a bed of two feet or more of fairly solid peat. This may be of Pleistocene or Recent age, or in part both.

In various parts of the Cascades there are cinder cones and lava streams which have every appearance of being of very recent origin. Some of these may be not much over a hundred years old. Indeed very carefully sifted newspaper stories and accounts by pioneers make it reasonably clear that volcanic activity persisted in the Cascade region until a very late day. The *Portland Oregonian* reports an eruption from Mount Hood as late as 1865.

Fig. 3.—Principal mineral localities in Oregon

GEOLOGIC HISTORY

The basement, upon which the Oregon strata appear to lie may be represented by the Bald Mountain gneiss of the Blue Mountains. The chemical composition of this supposed Archean rock indicates a sedimentary origin. Similar gneisses in Idaho and California possibly suggest a wide extension of a sedimentary terrain subsequently removed by erosion, or covered by younger deposits.

In the late Proterozoic southwestern Oregon became a basin of deposition in which the presumably conformable Abrams and Salmon formations were developed. This epoch of sedimentation was followed by a period of folding and accompanied by metamorphism which altered these rocks to mica and hornblende schists. An erosional interval extending over several geologic periods preceded the depression, in the middle Paleozoic of this same region, allowing the sea to enter from the southwest. The earlier sediments of this marine basin, now tentatively assigned to the Devonian system record a transgressing sea, with frequent oscillations from deep to shallow waters. Little is known regarding the climatic

conditions in Oregon, yet judging from other evidences these seas elsewhere teemed with corals, indicating tropical conditions. By Carboniferous time this, or a later sea in which crinoids lived, also covered a portion of the Blue Mountains of northeastern Oregon, which approximately marks the easternmost extension of that arm of the sea. The presence of tuffs and vesicular lava in the southwest gives a glimpse of volcanic activity upon the adjacent land mass.

Continental movements culminating in the Appalachian revolution caused a general retreat of the oceans to the outer edges of the continental shelf. In Oregon the Paleozoic sediments of both the southwest and northeast were uplifted, folded, and somewhat metamorphosed, though the principal orogenic movements of the Klamath region may have occurred later.

A long erosion interval followed, longer perhaps in the southwest than in the Wallowa Mountain region, for there the record of a shallow, oscillating sea, with a shore line not far to the southeast, is found in the Eagle Creek series of Triassic age. The meager fauna suggests little of the probable mild climate that prevailed.

During the Triassic and the earlier Jurassic the Klamath region of California and Oregon was probably land, and is thought by Diller to have been the scene of vigorous volcanic activity, the record of which is still seen in California along the southern margin of that land mass. If an early Mesozoic sea ever covered that region its record is yet to be discovered.

A few lower marine Jurassic fossils from the southwestern flank of the Blue Mountains is the only record of the Jurassic of eastern Oregon. This sea, skirting the slowly rising Blue Mountains probably did not extend far into Idaho, and it may have received the sediments from a great westward-flowing stream occupying the Snake River valley of Idaho.

Late in the Jurassic an epoch of sedimentation, known as the Galice, was again initiated in southwestern Oregon by the development of a basin in which diverse marine and possibly terrestrial beds accumulated. The meager fauna from these or even later Jurassic beds in Oregon tells little of the probable boreal aspect of

these seas. In California this boreal sea followed the warmer one of the Middle Jurassic, in which reef-building corals abounded.

It is not unlikely that minor diastrophic movements intervened between the close of the Galice and the opening of the Dothan-Franciscan time. During this succeeding epoch sediments accumulated in a basin in part coextensive with that of the Galice. Some of these were terrestrial deposits developed under arid conditions, while others point to the not infrequent recurrence of marine conditions. That the climate was more humid and warmer during at least a part of this epoch seems to be vouched for by the remarkable flora obtained from Nichols, Douglas County, Oregon, which includes cycads, ferns, ginkgoes, and conifers. This remarkable flora is said to be the richest of that obtained from any Mesozoic locality.

This period of sedimentation was followed by a great mountain-building epoch at or near the close of the Jurassic, resulting in the uplift of the Sierra, Klamath, and Blue mountains to greater altitudes than they had yet attained. These movements resulted in folding and faulting of the strata involved, and were accompanied, if not caused, by the intrusion of the Siskiyou tonolite batholith, and other types of igneous rock in the southwest, giving the main structural features to the Klamath Mountains as well as greatly metamorphosing many of the rocks involved.

In eastern Oregon "after the deposition of the Trias followed another and more extensive uplift, probably the same which affected the whole of the Pacific slope. Both the Triassic and Paleozoic series were folded . . . . the Trias were violently compressed in the area now occupied by the Wallowa Mountains. The uplift was accompanied by very extensive intrusions of granular rocks."[1] Thus the Blue Mountains in late Jurassic and Cretaceous times must have been a range of imposing height having a general eastward and westward trend.

The principal metallic deposits of southwestern and northeastern Oregon are genetically related to these igneous intrusives. The earlier epoch of mineralization occurring in the Paleozoic was of

[1] W. Lindgren, *U. S. Geol. Surv., 22d Ann. Rept.*, p. 596.

lesser importance. The latest occurred after the extrusion of the Columbia lava in the Miocene, followed by late Tertiary and Quaternary concentrations as placers or secondary enrichments.

Marine conditions were again initiated in later Knoxville time by the advance of an arm of the sea along the northern flank of the then partially dissected Klamath Mountains. The erosion preceding and continuing into this epoch had partially lowered those mountains and had exposed rich quartz lodes to the actions of the streams. Gold was thus washed out and deposited in the basal gravels of the transgressing Cretaceous sea. By upper Knoxville time the cold sea-waters of that time were cutting in the Franciscan rocks near Roseburg and were possibly skirting the foothills of the Blue Mountains. The meager boreal fauna of this sea gave way to the abundant tropical life of the Horsetown Sea, which was coextensive, in southwestern Oregon at least, with that of the preceding epoch. A rich Shasta flora upon the adjacent land gives another glimpse of the forests of Oregon.

In Chico time the sea, still teeming with tropical species of Indo-Pacific affinities, entered the Rogue River basin and ultimately reached the foothills of the Blue Mountains, possibly connecting through the ancient Lassen Strait with a California sea forming the Siskiyou Island of Condon.

This marine epoch was brought to a close by the epeirogenic and orogenic movements of the Laramide revolution, resulting in the final withdrawal of the sea from eastern Oregon, the uplift of the Klamath region, the folding and faulting of the strata, and the intrusion by basic igneous rocks. It is not improbable that a minor uplift along the axis of the present Cascades occurred at that time, forming an effective barrier to the earlier Tertiary seas. A long interval of erosion followed, which is in part represented in California by the Martinez Eocene. During this time much of the Cretaceous sediment was carried away, and southwestern Oregon was reduced to a region of low relief before the next depression in western Oregon admitted a tropical Tejon Eocene sea over western Oregon as far south as Roseburg and the mouth of the Rogue River. Thousands of feet of silts and sands were deposited in this shallow sea, which at times retreated locally, permitting the

swampy conditions now indicated by seams of coal. Volcanic activity again broke forth, producing basaltic and diabasic masses, some of which still form conspicuous heights of the northern Coast Range.

The Klamath region was being still lowered by erosion, and fluvatile and lake deposits equivalent in part to the Ione Eocene were formed in local basins. Along the western flanks of the Blue Mountains considerable thicknesses of rhyolitic ash and andesitic flows of the Clarno Eocene suggest the presence of volcanic vents to the westward. Still farther east along the Idaho-Oregon boundary local changes in drainage, due perhaps to blocking of channels by lava flows, or faulting, caused the deposition of the stream and lacustrine deposits of the Payette. These terrestrial beds give evidence of a tropical flora the remains of which, accumulating in various terrestrial and estuarine basins of the state, have since changed to the valuable coal seams of the Pacific Coast.

Only slight deformative movements intervened between the Clarno Eocene and the John Day Oligocene of eastern Oregon, but in the southwest an uplift occurred at the close of the Eocene that inaugurated the conditions which during the two succeeding geologic periods produced the Klamath peneplain. In the meantime the Eocene marine sediments had been gently folded, and the northwestern portion of Oregon was again depressed, allowing the Oligocene sea to reach the region of the present site of the Cascades and extend southward at least to Eugene. Near the shore of this subtropical sea tuffaceous deposits indicate volcanic activity to the eastward. Similar activity is conspicuously represented in some of the tuffs of the John Day Oligocene, which may be in part the correlative of marine Oligocene. The terrestrial deposits of the John Day, according to Merriam, were formed along the flood plains of an old-age stream. These lowlands were the habitat of oreodons, primitive dogs, saber-tooth cats, rhinoceroses, three-toed horses, and numerous other forms well known through the classical studies made upon this fauna.

The marine Oligocene was deformed, to an extent as yet undetermined, before the advance of the less extensive Monterey Sea. These waters were still warm, possessing a fauna similar to that of

California, yet apparently deficient in diatamaceous and radiolarian remains which are associated with the petroliferous deposits of that state. Volcanic activity then became the dominant feature of the period. Olivine basalts, issuing from fissures and vents along the axis of the present Cascades and throughout eastern Oregon, formed vast floods of lava, which rose high upon the flanks of the Blue Mountains. These flows were intermittent, as is attested by interbedded lateritic deposits, frequently containing petrified wood. This epoch of volcanic activity came to a close in middle Miocene time. In the John Day region these lavas were flexed, faulted, and partially eroded before the deposition of the middle Miocene Mascall in structural or erosional basins. Along the axis of the present Cascades these flows were thrown into an anteclinorum now exposed within the gorge of the Columbia. This epoch of deformation was of more than state-wide significance, being recognized in Washington and California.

The upper Miocene record of Oregon west of the Cascades is read mainly in the details of the later history of the then peneplained Klamath region. The marine epoch of Empire time is now thought to be early Pliocene. The upper Miocene floras of adjoining states and that of the eastern Oregon Mascall indicate a moist, warm, temperate climate, in which the camel, the horse, the ancient bear, and the proboscidians thrived. By the close of the Miocene, movements again interrupted the sedimentation in the John Day region, which deformed the Mascall beds. Upon their eroded edges were deposited gravels, tuffs, and flows of the early Pliocene.

Other local lake and flood plain deposits of later Pliocene age occur nearer the Idaho line, giving evidence of the formation of structural basins or changes in drainage as yet but imperfectly deciphered. A depression of a narrow strip paralleling the present shore line developed along the coast in early Pliocene and received the marine sediments of the Empire. The fauna of this sea indicates a cooler climate. This marine epoch was brought to a close by the epeirogenic movements which elevated the entire coast, producing the gentle folds now found in the Empire, probably the faulting and warping of the Klamath peneplain, and perhaps the

formation of the block mountains of eastern Oregon. Erosion soon cut these soft Empire sediments nearly to a base level, producing a second peneplain passing eastward over the Coast Range. Differential uplift within the Klamath and Coast Range regions again rejuvenated the streams, which intrenched themselves, maintaining in some instances their old, meandering courses. In late Pliocene or early Pleistocene these same streams cut deep valleys in the then exposed continental shelf, as is now revealed by soundings. The ancient Willamette River may then have carved in part its wide valley, since deeply filled by alluvium. In the meantime the Cascades had been reduced to a region of low relief covered, near the Columbia at least, by gravels of supposed Satsop age.

Following the deposition of these gravels came the final uplift of the Coast Range of Oregon and the extrusion of andesites and rhyolites forming the superstructure of the Cascade Range and the later development of the volcanic cones now dominating the crest line. Climatic changes that had been presaged by the cooler Pliocene climate culminated in the formation of glaciers on the higher peaks of the Cascades, Stein, Blue, and Wallowa mountains. These glaciers soon extended far down their valleys. The cooler and moister climate permitted the development of extensive lakes within the now semiarid region of eastern Oregon.

The life of the earliest Pleistocene is best interpreted from the rich avifauna of Fossil Lake and the marine fauna from a few very local embayments bordering the coast.

The disappearance of most of the Pleistocene glaciers, the deepening of river canyons, the development of alluvial deposits, including auriferous gravels, and the continued volcanic activity include the salient features of late Pleistocene and Recent time.

IGNEOUS ROCKS

Igneous rocks are found conspicuously developed in three regions in Oregon: (*a*) the Blue Mountains, (*b*) the Cascades, and (*c*) the Klamath Mountains. In the Blue Mountains the dominant type is granodiorite, in the Cascades basalt and andesite, and in the Klamath serpentinized peridotite, gabbro, and granodiorite.

Table I, compiled by Mr. Fred Melzer, a Senior in the department of Geology at Oregon in 1917, gives at a glance most of the general information about our igneous rocks, such as types, localities, frequency of mention in the literature, and the literature citation. From a study of the literature we find that, judging from the number of times mentioned in the literature, the various types of basalt come first, andesites next, followed by metagabbro third, and then comes rhyolite with diabase and diorite a little farther in the rear.

The dominant rock in the Cascade region is the Columbia lava, which is basaltic. The principal rock in the Cascade superstructure is andesite. In the metalliferous districts of the southwest and northeast granodiorite is the chief rock. For a petrographic description of this and the following rocks the reader is referred to Table I.

The serpentinized peridotites in the vicinity of Port Orford are both interesting and valuable economically because of the association of chromite and nickel. According to Diller they were probably intruded in Cretaceous times.

It will be seen from the testimony of the literature that the dominant igneous activity in the state has occurred later in geologic time, in the Mesozoic and Cenozoic. Very little is definitely known of the igneous rocks of the Paleozoic, and little or nothing of the pre-Cambrian, if indeed there were any at all at that time in this state.

Chemically the rocks are alkali-calcic. According to Iddings,[1] "the 76 igneous rocks of the Cascade Mountains that have been analyzed belong in 24 magmatic divisions of the Quantitative system, 56 falling in 5 divisions: tonolose 22, lassenose 11, andose 9, hessose 8, and yellowstones 6, all of which are dosodic. Only 9 of the 76 analyzed are sodipotassic."

Steinmann[2] asserts that the average igneous rock of the South American Cordillera is similar to that of the Pacific Coast of North America. He says that the lavas of the former region are andesites, dacites, and rhyolites, and that granodiorites are the pre-

[1] J. P. Iddings, *Igneous Rocks*, II, 446.

[2] G. Steinmann, *Geolo. Rundschau*, I (1910), 13.

Name	Age	Mineral Composition	Texture	Authority	Localities	Remarks
	I. PLUTONIC ROCKS					
Granites: Hornblende biotite granite	Post-Triassic	Like hornblende-biotite granite-augite altering to hornblende		Grant and Cady*	Haines, Baker Co.	
Soda granite	Post-Triassic	Quartz, albite, small amount of ferromagnesian minerals, mostly chlorite	Granular	Lindgren	Sparta, Baker Co.	
Granite from White Point		Abundant orthoclase, some plagioclase, quartz, biotite, muscovite, and accessories		A. N. Winchell	White Point, Jackson Co.	
Granodiorite	Late Mesozoic	Abundant sodic plagioclase = (andesine-oligoclase), subordinate orthoclase and microcline, some quartz; biotite, green hornblende, titanite, pyrite, magnetite, apatite, and zircon	Medium-grained, hypidiomorphic, granular	Lindgren Pardee* Swartley* Calkins, p. 11 S. A. N. Winchell Diller	Bald Mt. batholith, Baker Co. Wallowa Mts. John Day Basin, Middle Fork Josephine and Jackson Cos.	It is with this rock, especially in the Blue Mts., that the gold-bearing quartz veins are associated.
Tonalite		Sodic plagioclase, quartz, hornblende or biotite, or both, and accessories		A. N. Winchell	Josephine and Jackson Cos.	
Diorite		Sodic plagioclase, hornblende or biotite, or both, accessories	Dark gray granular rock	Lindgren A. N. Winchell Pardee and Hewitt*	Baker Co. Josephine and Jackson Cos.	Occurs as marginal variation of granodiorite and tonalite batholiths in both localities.
Diorite porphyry		Larger crystals of plagioclase feldspar, augite, hypersthene, in finer matrix of same minerals plus possibly some quartz	Holocrystalline	Ira A. Williams	Shellrock and Wind Mts. Columbia River	This rock is of the plutonic type, since it occurs as an intruded batholith, in spite of the name "porphyry." It is possible that further work may identify it with one of the other types described.
Metagabbro	Pre-Tertiary	Calcic plagioclase; abundant augite, mostly altered to hornblende or chlorite; or also secondary quartz, muscovite, epidote, and kaolin	Granitic texture, at times ophitic	Lindgren Pardee and Hewitt A. N. Winchell Diller	Blue Mts. Josephine and Jackson Cos. Port Orford Quadrangle Roseburg Quadrangle	These rocks are alteration products of fresh gabbro, which itself is nowhere prominent. Winchell employs the term. Sonsurite (= Metagabbro).
Norite		Plagioclase and inclosed hypersthene; intergrown with pyrrhotite, chalcopyrite, etc.		A. N. Winchell	Chisholm's copper mine on Evans Creek, Jackson Co.	
Peridotite	Paleozoic (Pardee)	Olivine; pyroxene, amphibole, or both	Coarsely crystalline, heavy, dark rock	A. N. Winchell Pardee and Hewitt*	Riddle, Douglas Co. Along McCully's Fork, Sumpter	
Dunite		Olivine; little pyroxene or amphibole	Olivine, often altering to serpentine	A. N. Winchell	Spanish Gulch and Beach Cr. John Day Valley.	Winchell mentions Dunite as a variation of peridotite, in the case where

Norite		Plagioclase and inclosed hypersthene; intergrown with pyrrhotite, chalcopyrite, etc.		A. N. Winchell	Chisholm's copper mine on Evans Creek, Jackson Co.	
Peridotite	Paleozoic (Pardee)	Olivine; pyroxene, amphibole, or both	Coarsely crystalline, heavy, dark rock	A. N. Winchell Pardee and Hewitt*	Riddle, Douglas Co. Along McCully's Fork, Sumpter	
Dunite		Olivine; little pyroxene or amphibole	Olivine, often altering to serpentine	A. N. Winchell	Spanish Gulch and Beach Cr. John Day Valley. Waldo Mine at Takilma, Josephine Co.	Winchell mentions Dunite as a variation of peridotite, in the case where olivine becomes the dominant constituent.
Pyroxenite	Pre-Eocene (Calkins)	Pyroxene	Coarsely crystalline	Calkins, p. 118 A. N. Winchell	Red Mt.	The two varieties described differ considerably.
Diabase	Eocene (Diller)	Augite, generally uralitized; lime-soda feldspar; sometimes olivine	Fine-grained, dense rock, ophitic structure	Diller Lindgren	Roseburg Quadrangle Blue Mts.	
		II. HYPERBYSSAL (DIKE) ROCKS				
Granite porphyry	Pre-Eocene	Phenocrysts: orthoclase; quartz; plagioclase; in groundmass biotite, apatite, magnetite and zircon	Porphyritic, holocrystalline groundmass	Calkins, p. 117	Spanish Gulch, Wheeler Co.	
Syenite porphyry		Orthoclase and hornblende	Porphyritic	Butler and Mitchell	Curry Co., Mt. Emily	The descriptions given for these two types are not sufficiently detailed to enable placing them accurately.
Granodiorite porphyry		Feldspar and hornblende	Fine groundmass	Swartley	Blue Mts.	
Aplite		Abundant microcline or orthoclase, or both, and quartz. Some plagioclase, biotite, and accessories		A. N. Winchell Pardee Swartley	Josephine and Jackson Cos. Blue Mts.	
Tonalite-aplite		Plagioclase and quarts, little biotite or hornblende		A. N. Winchell	Grant's Pass, Josephine Co.	
Pegmatite		Quartz and microcline, coarse muscovite, little plagioclase	Coarse texture	A. N. Winchell Pardee Lindgren	Evans Creek, Jackson Co. Blue Mts.	Lindgren describes a rare pegmatite from the Coyote Hills, Baker County.
Dacite prophyry		Phenocrysts: feldspar (labradorite), less prominently quarts, some hornblende or chlorite	Porphyritic; crystalline groundmass of quarts and feldspar	Diller	Port Orford Quadrangle Bohemia mining region Grant's Pass, Josephine Co.	
Malchite		Abundant sodic plagioclase, hornblende, sometimes quarts	Aplitic texture	A. N. Winchell	Ashland mine and other localities in Josephine and Jackson Cos.	Winchell's malchite is very closely related to Diller's dacite porphyry, the main difference being texture.
Kersantite		Biotite and plagioclase		A. N. Winchell Lindgren	Josephine and Jackson Cos. Blue Mts.	
Spessartite		Abundant hornblende and some plagioclase		A. N. Winchell	Near Jacksonville	
		III. VOLCANIC ROCKS				
Rhyolite	Eocene or later (Calkins)	Phenocrysts: quarts, alkali feldspar (orthoclase or sanidine), oligoclase, accessories	Light-colored rocks, glassy groundmass, often devitrified in whole or part	Calkins, pp. 141 and 152 Diller Lindgren Pardee	Clarno's Ferry \ John Day Antelope Valley / region Roseburg Quadrangle Blue River mining district	Calkins and Lindgren describe types with microcrystalline and cryptocrystalline groundmass. Calkins also described a fibrous ground-

				Lindgren	Blue Mts.	
Spessartite		Abundant hornblende and some plagioclase		A. N. Winchell	Near Jacksonville	
			III. VOLCANIC ROCKS			
Rhyolite	Eocene or later (Calkins)	Phenocrysts: quartz, alkali feldspar (orthoclase or sanidine), oligoclase, accessories	Light-colored rocks, glassy groundmass, often devitrified in whole or part	Calkins, pp. 141 and 152 Diller Lindgren Pardee Winchell	Clarno's Ferry | John Day Antelope Valley / region Roseburg Quadrangle Blue River mining district Blue Mts. Josephine and Jackson Cos.	Calkins and Lindgren describe types with microcrystalline and cryptocrystalline groundmass. Calkins also described a fibrous groundmass. Sometimes the groundmass shows considerable alteration
Spherulitic type	Eocene	Phenocrysts: quartz, sanidine, and acid plagioclase, all sparingly present	Lithoidal groundmass containing large and small spherulites	Calkins, p. 138	Current Creek Hill, John Day region	
Obsidian			Glassy acid rock	Russel	S.E. Oregon	
Rhyodacite		Phenocrysts: plagioclase and orthoclase in a fine quartz matrix		A. N. Winchell	Galice district, Josephine Co.	
Dacite		Phenocrysts: plagioclase and quartz; groundmass of plagioclase, quartz, etc.	Groundmass, hypocrystalline	A. N. Winchell Lindgren	Galice district, Josephine Co. Hereford, Baker Co.	
Hypersthene dacite		Phenocrysts: labradorite, hypersthene, brown hornblende; sometimes augite and olivine. Groundmass varies in different types	Porphyritic, groundmass varies from glassy to crystalline	Patton, pp. 3, 99–141	Crater Lake	Dacites are the latest flows seen on rim of Crater Lake.
Andesites: Hornblende andesite	Eocene or later (Calkins)	Phenocrysts: labradorite and more acid feldspar, brown pleochroic hornblende, accessory apatite and magnetite. Groundmass, andesine feldspar, etc.	Porphyritic, groundmass minutely crystalline	Calkins, pp. 128–29 Lindgren Diller	Hald's Canon Burnt River and Middle Fork, John Day Bonneville and Cascades	
Hornblende hypersthene andesite	Clarno and later (Calkins)	Phenocrysts: basic labradorite, iddingsite pseudomorphs after hypersthene, hornblende, zeolites	Porphyritic, groundmass, hyalopilitic	Calkins, p. 129 Diller	Clarno's Ferry Bonneville Mt. Hood, Cascades	Feldspars in part altered to stilbite and heulandite which Calkins calls characteristic of Clarno andesites.
Hypersthene andesite	Pleistocene Clarno (Calkins)	Phenocrysts: basic plagioclase, hypersthene, augite, magnetite, seldom olivine and hornblende	Groundmass distinguishes two types (Patton): A. Hyalopilitic B. Hypocrystalline 1. Docitic 2. Holocrystalline	Patton, pp. 69–99 Calkins, pp. 122–28 Lindgren, p. 592	Crater Lake Hald's Canon Susanville to Prairie Cascades	The andesites are the oldest of Crater Lake effusives. Calkins' hypersthene shows alteration to iddingsite.
Augite andesite		Phenocrysts: plagioclase, augite, at times hypersthene, but subordinate to augite	Minutely porphyritic, groundmass somewhat ophitic	Diller	Roseburg Quadrangle Grant's Pass Quadrangle Bohemia mining district	Although no such full descriptions are given for this rock as for the foregoing, the evident subordinate character of the hypersthene makes possible distinction.
Basalts: Olivine basalt	Miocene	Basic plagioclase (labradorite); common pale brown augite, subordinate olivine, iron ore; apatite, secondary iddingsite and zeolites	Groundmass intersertal to ophitic holocrystalline	Calkins, pp. 159–65 Diller Lindgren A. N. Winchell	Eastern Oregon Coos Bay and Roseburg Quadrangles Josephine and Jackson Cos.	This includes the widespread "Columbia River Lavas."
Olivine-free basalt	Mascall (Calkins)	Basic plagioclase, augite, abundant accessory magnetite	Groundmass is typically intersertal	Calkins, pp. 165–66 Lindgren	John Day basin	This includes Winchell's auganite.

Hypersthene andesite	Pleistocene Clarno (Calkins)	Phenocrysts: basic plagioclase, hypersthene, augite, magnetite, seldom olivine and hornblende	Groundmass distinguishes two types (Patton): A. Hyalopilitic B. Hypocrystalline 1. Docitic 2. Holocrystalline	Patton, pp. 69–99 Calkins, pp. 122–38 Lindgren, p. 592	Mt. Hood, Cascades Crater Lake Hald's Canon Susanville to Prairie Cascades	and hedlandite which Calkins calls characteristic of Clarno andesites.
Augite andesite		Phenocrysts: plagioclase, augite, at times hypersthene, but subordinate to augite	Minutely porphyritic, groundmass somewhat ophitic	Diller	Roseburg Quadrangle Grant's Pass Quadrangle Bohemia mining district	The andesites are the oldest of Crater Lake effusives. Calkins' hypersthene shows alteration to iddingrite.
Basalts: Olivine basalt	Miocene	Basic plagioclase (labradorite); common pale brown augite, subordinate olivine, iron ore; apatite, secondary iddingsite and zeolites	Groundmass intersertal to ophitic holocrystalline	Calkins, pp. 159–65 Diller Lindgren A. N. Winchell	Eastern Oregon Coos Bay and Roseburg Quadrangles Josephine and Jackson Cos.	Although no such full descriptions are given for this rock as for the foregoing, the evident subordinate character of the hypersthene makes possible distinction.
Olivine-free basalt	Mascall (Calkins)	Basic plagioclase, augite, abundant accessory magnetite	Groundmass is typically intersertal	Calkins, pp. 163–66 Lindgren	John Day basin	This includes the widespread "Columbia River Lavas."
Quarts-bearing hypersthene basalt	Eocene (Calkins)	Phenocrysts: pleochroic hypersthene and green augite, olivine, quarts showing magmatic corrosion. Microlites of labradorite	Feltwork groundmass of pyroxene, feldspar, and brown glass	Calkins, pp. 134–46	Cherry Creek, John Day basin	This includes Winchell's auganite.
Hypersthenebasalt	Post-Tertiary	Very basic plagioclase, augite, hypersthene olivine, magnetite	Structure, interstitial to porphyritic	Patton, pp. 141–63	Crater Lake	
Andesitic basalt		A type approaching in composition and structure Patton's hypersthene andesite above		Patton	Crater Lake	Occurs only as flows from cones on outer slope of Mt. Mazama. Russel's Pleistocene basalt of southeastern Oregon may belong here.
Augitite		Pyroxene		A. N. Winchell	Takilma, Josephine Co.	

*M. R. of O.=Mineral Resources of Oregon.

vailing intrusives. In this connection Becker and W. D. Smith have repeatedly called attention to the relation between the igneous rocks of the Philippines and of Oregon. If we pass a great circle along the axis of the Cascades we shall find that it will pass remarkably close to the Cordilleras of Japan and the Philippines, and it is only to be expected that we would find this petrographic similarity along such a great and persistent tectonic line.

Definite figures as to the size of the intrusive batholiths in Oregon are at present unavailable. In the Blue Mountains the granodiorite is very prominent and attains elevations close to 10,000 feet and covers hundreds of square miles, while in the Cascade region it is seen in one or two localities only, and these low down and in very limited exposures. In the Siskiyou region (southwest) also there are large masses of granodiorite.

ECONOMIC GEOLOGY

In 1867 the mineral production of Oregon, according to government estimates at that time, was about twenty million dollars and was practically, if not entirely, from gold placers.

In 1917 the value of the mineral products of the state which were mined amounted to about $3,500,000. The year 1918 saw slightly less, owing to war conditions. A few years ago the production was almost nil, so that we are now on the upgrade again, and a substantial gold-mining industry largely from quartz lodes is being established.

On the mineral map (Fig. 3) are shown the principal mineral localities in the state. It will be seen from a glance that the two metalliferous districts are in the southwest and in the northeast, the Siskiyou and Blue Mountains respectively. Baker County produces the larger part of the gold of Oregon, and the Cornucopia district is the leading district of that county.

While there are many copper prospects, the most noteworthy are those near Homestead on the Snake River, and those near Waldo, twenty miles southwest of Grant's Pass, in the southwestern part of the state.

During the war there was a rather notable development of the chromite industry in these two regions, and one manganese locality

(Lake Creek) was being vigorously prospected, with the hope of a substantial production very soon.

Some platinum is recovered with gold in the beach placers to the north and south of Marshfield, but the yield has not yet had any appreciable effect on the industry.

Nickel deposits occur near Riddles, Douglas County, but no production is reported at the present time.

One quicksilver mine is located near Cottage Grove, Lane County, which, however, has not had a very prosperous history.

Common brick and drain tile are made at many localities in Oregon, but clays suitable for pottery of the better grades have either not been located, or if known, have not been worked.

All attempts to find oil in commercial quantities in Oregon have so far failed. At the present time drilling is being done near Waldport on the coast, and near Roseburg and Vale on the eastern boundary of the state. So far no success has been met in these undertakings. Near McMinnville, Yamhill County, there are several salt springs and gas wells, one of which in Polk County illuminates a ranch house and is used for cooking. This well has given off natural gas for over thirty years. No scientific development of this field has yet been undertaken. It seems to be the most promising place in Oregon for natural gas, and possibly petroleum. Some "shows" of oil have just recently been reported from a Harney County (southeastern Oregon) well, now down to 1,241 feet.

A fair grade of sub-bituminous coal of Tertiary age is mined in the small basins of marine Tertiaries near the coast. The production is small and comes from two or three small mines. The daily output probably has never exceeded fifty tons.

A great deal of crushed stone, mainly basalt and diabase, is utilized annually on our highways. Limestone is found in both the northeast and southwest portions of the state. The product is distributed largely by the State Lime Board.

The most valuable and unique decorative stone, a handsome black marble, anywhere in the state and perhaps anywhere in the Pacific Northwest is quarried near Enterprise, Wallowa County.

The state of Oregon cannot be said to be a mining state, though it has a promising future in this direction. The state is very

wisely doing something to aid this important industry in supporting a State Bureau of Mines; an appropriation of $50,000 for the biennium has just been granted it.

MINERAL PRODUCTION IN OREGON*

FOR 1917

Gold	$1,491,798.00
Platinum	65 ounces
Silver	125,656 fine ounces
Copper	2,474,487 pounds
Chromite	6,700 tons
Lead	28,000 pounds

NON-METALS, 1916

Coal	42,592 tons
Mineral water	30,920 gallons
Building sand and gravel	161,761 tons
Crushed stone (1917)	282,732 tons

*By courtesy of Charles G. Yale, statistician, United States Geological Survey.

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SOME SUBORDINATE RIDGES OF PENNSYLVANIA

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The topography of the folded mountain district of Pennsylvania consists of the narrow valleys and long, even-crested ridges cut by occasional water gaps and wind gaps which are familiar to the geologist and geographer the world over. For nearly a third of a century, since the publication of the epoch-making essay by Davis,[1] this region has been classic for the study of the peneplain. The tops of the even-crested ridges are said to represent the remnants of a surface which has been variously named the Cretaceous baselevel lowland,[2] the Schooley peneplain,[3] and the Kittatinny peneplain.[4] With the precise dates of formation of this supposed peneplain and the valley lowlands, generally called the Harrisburg peneplain,[5] we are not concerned here.

The formations sufficiently resistant to be ridge makers in Center County and neighboring counties are the Oneida and Medina sandstones of the earlier geologists, now known as the Oswego and Tuscarora respectively, separated stratigraphically by 490 to 850 feet[6] of the Juniata formation, consisting of soft red shales and sandstones. Of the two sandstones the Tuscarora is by far the more resistant to erosion, and accordingly in many instances

[1] W. M. Davis, "The Rivers and Valleys of Pennsylvania," *Nat. Geog. Mag.*, I, No. 3 (1889), pp. 183–253.

[2] *Ibid.*, p. 198.

[3] W. M. Davis and J. W. Wood, Jr., "The Geographic Development of Northern New Jersey," *Boston Soc. Nat. Hist., Proc.*, XXIV (1890), 377.

[4] Bailey Willis, "The Northern Appalachians," *The Physiography of the United States, Nat. Geog. Soc., Mon.*, I, No. 6 (1895), p. 189.

[5] M. R. Campbell, "Geographic Development of Northern Pennsylvania and Southern New York," *Geol. Soc. Am., Bull.*, XIV (August 5, 1903), 283–84.

[6] E. S. Moore, Unpublished data. Also Charles Butts, "Geologic Section of Blair and Huntingdon Counties, Central Pennsylvania," *Am. Jour. Sci.*, XLVI (September, 1918), 536.

on the limbs of close folds the topography finds expression in the close association of two ridges of different heights, usually with an intervening lowland on the soft Juniata formation. The discrepancy in height is not universal, as in several places in the Bellefonte quadrangle the Oswego ridges equal and even exceed in height those of the Tuscarora. It is the purpose of this article to show that these "subordinate ridges" as Willis[1] styles them, are more numerous than hitherto suspected, that their origin and existence have not been explained satisfactorily by physiographers, and that they constitute a menace to the validity of the Cretaceous peneplain theory.

The existence of subordinate ridges is noted by Willis[2] as follows:

> The simple monoclinal ridge which has been described is the typical but not the more common form of the Appalachian ranges. They become complex by association of parallel ridges. Thus on the inner slopes of Jacks and Stone mountains, about Kishicoquillas valley, there is a very marked bench or terrace, which appears as a broad step in the mountain slope. In other localities, when the outer edge of such a terrace is higher than its surface nearer the mountain, there are narrow ravines separating the terrace edge as a low ridge more or less distinct from the mountain itself. . . . . Elsewhere, again, ... the subordinate ridge may stand at a level equal with the continuous crest, and it then appears as a distinct monoclinal ridge.

The Stone Mountain referred to is the southernmost of the series of great consecutive ridges known as the Seven Mountains, which bound the Nittany valley on the south and is immediately north of the Kishicoquillas valley.

Davis[3] recognizes the existence of subordinate ridges:

> The beds of intermediate resistance, the Oriskany and Chemung sandstones, had not been worn down to baselevel at the close of the Tertiary cycle; they had indeed lost much of the height that they possessed at the close of the previous cycle, but they had not been reduced as low as the softer beds on either side. They were only reduced to ridges of moderate and unequal height over the general plain of the Siluro-Devonian low country, without great strength or relief but quite strong enough to call for obedience from the streams along side of them.

[1] Willis, *op. cit.*, p. 182. [2] *Ibid.*, p. 182.

[3] W. M. Davis, "The Rivers and Valleys of Pennsylvania," *Nat. Geog. Mag.*, I, No. 3 (1889), pp. 243–44.

Again, in another article, he[1] says: "The weaker Siluro-Devonian beds are generally reduced to a lowland farming country, except where the Oriskany sandstone or a Chemung conglomerate of more resistance than the adjacent beds rises in ridges of moderate height. The hard Medina and Carboniferous sandstones hold their crests close to the Cretaceous peneplain."

Professor Davis assumes that the original height of the Oriskany and Chemung ridges equaled that of the Cretaceous peneplain surface but offers no confirmatory data. Apparently he does not distinguish clearly between the heights of the Oswego and Tuscarora ridges, but he may have this discordance in mind when stating[2] that the Medina crests accord with "geographic" rather than "geometric" exactness.

Years later Stose,[3] in comparing the high, even crest of Cross Mountain with the low, "comby" top of Cove Mountain in the Mercersburg-Chambersburg region in southern Pennsylvania, says: "It is apparent that Cove Mountain once stood at approximately this altitude, but has been lowered by the active erosion of the relatively narrow exposure of upturned rocks." Cross Mountain is supposed to be part of the old peneplain surface. Farther on in the same paper he says: "These two level tracts [referring to areas on South Mountain] are undoubtedly remnants of the old peneplain, preserved at the height of 2,000 feet. The monoclinal ridges along the front of the mountain, which once stood at this same altitude, have been reduced by erosion to 1,700 and 1,900 feet."[4] In these two quotations the height of a lower ridge is explained by reduction from the original peneplain.

Reverting to the Nittany valley and the Seven Mountains district, the following are altitudes[5] (obtained by barometer) on

[1] W. M. Davis, "The Geological Dates of Origin of Certain Topographic Forms on the Atlantic Slope of the United States," *Geol. Soc. Am., Bull.*, II (July 2, 1891), 572.

[2] *Ibid.*, p. 560.

[3] G. W. Stose, "Physiographic Studies in Southern Pennsylvania," *Jour. Geol.*, XII (1904), 476.

[4] *Ibid.*, p. 478.

[5] Charles E. Billin, "Map of Adjoining Portions of Huntingdon, Mifflin, Centre, and Union Counties," *Sec. Geol. Surv. Pa., Rept. of Progress S*, 1878.

the Tuscarora summits south of Potters Mills and Boalsburg: Broad Mountain, 2,300 feet; Millikens Knob, 2,200 feet; a crest two miles south of Boalsburg, 2,300 feet; the mountain on road south of Pine Grove Mills, 2,010 feet; Roberts Knob, 2,410 feet; and Bear Meadows Mountain, 2,100 to 2,200 feet. The same map gives the following readings for the Oswego ridge summits: a ridge running from Bear Meadows north of Roberts Knob 26 miles northeast to Woodward, 1,700 feet average, attaining 1,800 feet in a few places; a corresponding ridge one mile southeast of the preceding on the other limb of the syncline, averages 1,800 feet for many miles; Tussey Knob, east of Boalsburg, rises to an altitude of 2,100 feet, rapidly sinking to the southwest to 1,600 and 1,700 feet average.

Making allowance for possible slight inaccuracies in these map elevations a distinct discordance in height between the summits of the Oswego and Tuscarora ridges, in general, becomes manifest from the foregoing data. This discordance may be observed in the field, either from one of the higher and more commanding points on the Nittany valley lowland, or from some coign of vantage in the Seven Mountains, such as Roberts Knob. After six years' residence in the Nittany valley the writer is convinced that this difference in summit levels in the central Pennsylvania district is an important factor which cannot be passed over with the facility of some previous writers.

Space does not permit here the enumeration of instances of the difference in heights of adjacent mountain ridges in other states, but one example will show how universal the phenomenon is. In the Hancock, Maryland-West Virginia-Pennsylvania quadrangle the Cretaceous peneplain has been obliterated entirely in all probability, according to Stose,[1] but is preserved in the 2,000- to 2,200-foot summit of Cacapon Mountain in the Pawpaw quadrangle. This author[2] distinguishes between the Somerville (New Jersey peneplain) terrace[3] varying from 600 to 850 feet in elevation,

[1] G. W. Stose and C. K. Swartz, "Pawpaw-Hancock Folio, Md.-W. Va.-Pa.," *U.S. Geol. Surv.*, No. 179 (1912), pp. 19–20.

[2] *Ibid.*, p. 20.

[3] Davis and Wood, *op. cit.*, pp. 391–92.

the so-called Harrisburg peneplain level of 700 to 1,000 feet shown in many even-topped ridges and intermontane floor areas, a series of ridges averaging 1,200 feet in height, which he correlates with the Weverton, Maryland, peneplain,[1] and "remnants of intermediate erosion plains" from 1,550 to 1,700 feet in height.

Facts such as the foregoing give rise to doubts and queries which are of more than local significance. To admit the inadequacy of the Tertiary erosion to reduce completely some subordinate ridges to the valley-plain level seems to be overlooking the question of their origin as much as does the affirmation that the height of subordinate ridges represents a lowering and modification of an original, higher peneplain surface. As the geologist follows for miles two closely parallel ridges of even crests but of different heights, he is likely to think, as the writer does, that the origin of the two is the same, and that any explanation of the method of development of the one should be applicable to the other also. If the one represents a portion of the dissected and mutilated surface of an older peneplain, likewise, by the same reasoning, the other must represent something; but by no stretch of the imagination can some of the lower ridges of Pennsylvania be considered peneplain remnants.

Many years ago Hayes[2] expressed the belief that a lower ridge with even crest can be produced by reduction from a higher peneplain, as "corrasion is practically absent and only the forces of erosion are in play. Hence if the ridge was originally level it might remain so indefinitely or until it had been reduced far below the former surface of the baselevel plain."

Dr. T. C. Hopkins,[3] whose experience in central Pennsylvania entitles him to express an opinion, explains the development of these low ridges—the terraces of "terraced mountains"[4]—by

[1] Arthur Keith, "Geology of the Catoctin Belt," *U.S. Geol. Surv., Fourteenth Ann. Rept.*, 1892–93, Part 2, p. 388. Also W. B. Clark and E. B. Mathews, "The Physical Features of Maryland," *Md. Geol. Surv.*, VI (1906), 87, 88.

[2] C. W. Hayes, "Physiography of the Chattanooga District, in Tennessee, Georgia, and Alabama," *U.S. Geol. Surv., Nineteenth Ann. Rept.*, 1897–98, Part 2, p. 27.

[3] Recent personal communication to the writer.

[4] T. C. Hopkins, *Elements of Physical Geography* (1908), pp. 338–39.

reduction from the original peneplain; but he believes that the stratigraphic sequence of the rock series in the Nittany valley region must be taken into account in this connection. He lays emphasis upon the fact that the Tuscarora is underlain by the Juniata, a formation comparatively soft but not nearly as soft as the Reedsville (Utica), which consists entirely of very fissile shale. Thus the Oswego ridges would tend to become undermined faster than those of the Tuscarora, and this fact, coupled with the initial difference in weathering quality between the two sandstone formations, would result in a consistent difference in height of the ridge crests.

Explanations of the present height of the lower ridges, involving a process of reduction from former higher ridges, would seem risky in view of the lengths to which such arguments can be carried. Once admitting the possibility of the lower ridges maintaining their even crests and owing their ultimate origin to differential erosion, is it illogical to explain the even crests of the higher ridges by gradual erosional development contemporaneous with and subsequent to the long period of folding? In short, arguing from the topography of the ridges only, is it necessary to postulate a Cretaceous peneplain at all?

The writer has no alternative theory to suggest and no view to advocate, but merely raises the question, feeling that the Cretaceous peneplain theory does not explain adequately the existence of these minor ridges.

Of late the word "peneplain" has been used rather loosely and has been applied to conditions where direct proof is lacking. It is easy to conclude hastily that a ridge or series of ridges represents a peneplain, but much harder to prove such a statement. By no means is every ridge or upland remnant the remains of a peneplain, and a word of caution to workers in this field seems in order.

Professor A. M. Miller[1] may voice the feelings of others than himself in the following words:

> . . . . when one examines the literature of modern physiography and sees the readiness with which an "uplifted and dissected peneplain" is invoked

[1] A. M. Miller, "Wind Gaps," *Science*, N.S., XLII, No. 1086 (October 22, 1915), p. 573.

to explain every even sky-line or approximate uniformity in heights of mountain summits, while every peculiarity in drainage is accounted for as an inheritance from a past cycle of erosion, overlooking in many cases a simpler explanation involving only "processes now in operation"; he wonders if there does not lurk therein somewhat of the old catastrophism.

The writer's thanks are due to Professors Davis and Hopkins for valuable criticism and suggestion in preparing this paper.

GLACIAL FEATURES ON THE SOUTH SIDE OF BEARTOOTH PLATEAU, WYOMING[1]

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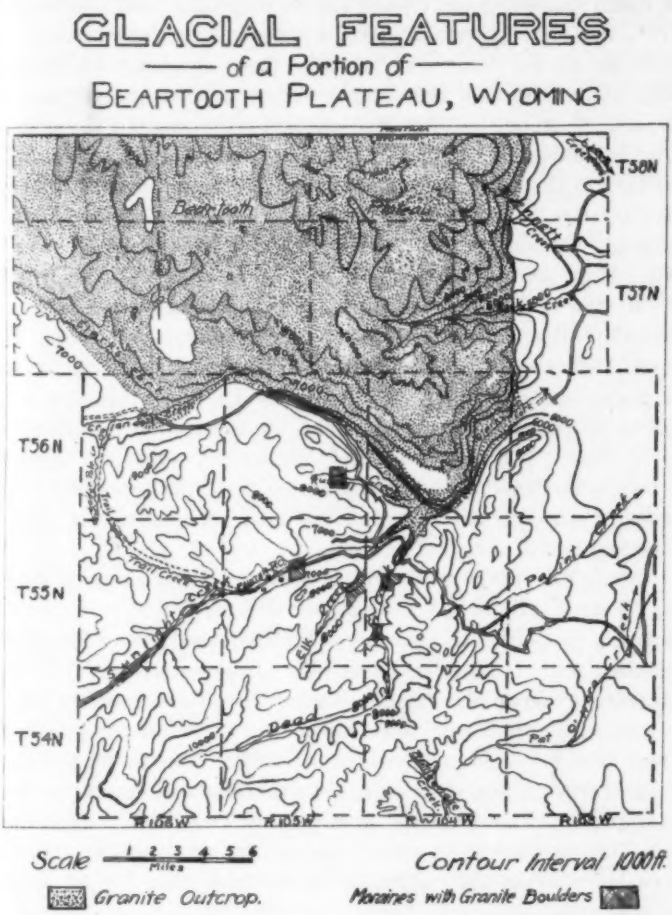
During the summer of 1916 the writer spent a number of days in the basin of Clarks Fork, along the southern margin of the Beartooth Plateau. In the course of the work there several interesting glacial features were noted. The general situation, together with the localities mentioned, are shown on the accompanying map, compiled from the Shoshone National Forest Map and from the Crandall Quadrangle.

That portion of the Beartooth Plateau lying between Clarks Fork and the Wyoming-Montana state boundary has been severely glaciated. The plateau averages over 10,000 feet in elevation and consists of bare, rounded knobs of granite, interspersed with lakes and swamps. Several of the northward-flowing streams that rise south of the state line head in typical cirques, occupied by small lakes. Glacial striae were noted at several points. The valleys of Line Creek and Bennett Creek, near where they emerge from their canyons in the granite on to the plains of the Bighorn Basin, are occupied by well-marked moraines. Little Rock Creek shows distinct evidences of glaciation but has a less pronounced moraine at the canyon mouth. There are slight evidences of a moraine at the mouth of the Clarks Fork canyon itself. On the south wall of that canyon numerous granite bowlders are to be seen several hundred feet above the contact of the Cambrian on the pre-Cambrian granite.

It is, however, in the valleys of Dead Indian Creek, Elk Creek, Sunlight Creek, and Russell Creek that the most interesting conditions obtain. In the Sunlight basin, a well-defined moraine occurs along the line between sections 15 and 16, T. 55 N., R. 105 W. It is referred to by Hewett, who says of it, "Sunlight Basin appears

[1] Published by permission of the Wyoming state geologist.

to owe its origin to the damming of a deep glacial valley by a terminal moraine, which is a prominent feature a mile below Painter



post-office, and behind which an accumulation of glacial gravel and lake sediment has formed the present valley floor."[1]

[1] D. F. Hewett, "Sulphur Deposits of Sunlight Basin, Wyoming," *Bull. U.S. Geol. Surv. No. 530*, p. 352.

Hewett failed, however, to call attention to the most marked and interesting feature of the moraine, namely, that the bowlders of which it is composed consist largely of granite, and this in spite of the fact that a careful search for many miles revealed no granite outcrops *up the valley* from the moraine. A glance at Hague's map of the Crandall Quadrangle[1] shows that in his mapping he located no granite outcrops in Sunlight valley within the area of that quadrangle, that is, in the area above the moraine. Almost as striking as the dominance of the granite in the moraine is the relative scarcity of andesite, although not far above the moraine in question the andesite walls of the basin close in, almost entirely cutting out the sedimentary series.

In view of the above-mentioned conditions the conclusion seems inevitable that the glacier moved up the valley, not down. The broad U-shape of the valley above the moraine may be due in part to glacial scour, the glacier at one time having occupied a more advanced position than it did when the moraine in question was being built. It is more than probable, however, that the U-profile is largely the result of the glacial fill resulting from deposition in the valley when occupied by the ice-dammed lake. Much of the old lake bed is still very flat and swampy.

Along Elk (Elkhorn) Creek, on the line between sections 13 and 24, T. 55 N., R. 105 W., is another well-marked moraine, in the bowlder-clay of which were noted striated bowlders of limestone, granite, and Deadwood flat-pebble conglomerate. Very little andesite occurs in the moraine, though the andesite walls close in completely, only about three miles above. A careful search up creek from the moraine to where the andesite covers all the older rocks shows no exposures older than the Madison limestone (Mississippian), although both granite and Deadwood (Cambrian) conglomerate bowlders were found occurring abundantly in the moraine. Again the conclusion is inevitable that the ice moved up the valley.

Similar conditions were noted well toward the head of Russell Creek, where moraines with very little andesite and much granite were found resting directly on andesite outcrops. Along Lodge

[1] Arnold Hague, *Absaroka Folio*, No. 52.

Pole trail, on the pass at the head of Lodge Pole Creek, granite bowlders were found high on the andesite slopes, nearly 1,500 feet above the contact of the Paleozoic series on the granite.

Similarly moraines on Dead Indian Creek carry much granite, and granite bowlders were noted on andesite outcrops on the south side of the low pass between the head of Dead Indian Creek and Rattlesnake Creek. This occurrence is eight miles south of any granite outcrop and nearly 2,000 feet above the contact of the Paleozoic upon the pre-Cambrian, near the mouth of Dead Indian valley.

In the light of these facts it would seem that the Beartooth Plateau was occupied by an ice cap that sent several tongues eastward into the edge of the Bighorn Basin, and a number southward across the Clarks Fork Canyon several miles *up the valleys* of Sunlight, Elk, Russell, and Dead Indian Creeks.

Reviews

The Permo-Carboniferous Ammonoids of the Glass Mountains, West Texas, and their Stratigraphical Significance. By Emil Böse. University of Texas Bulletin, No. 1762, Nov. 5, 1917.

The cephalopod faunas of the Permian are still imperfectly known in spite of the work of forty years in many parts of the world. The classic works of Karpinsky in Russia, Waagen in India, C. A. White in Texas, and Gemmellaro in Sicily have furnished the bulk of our knowledge of these interesting transitional forms. Dr. Böse has added a fifth to these classics, in his studies of the ammonoids of western Texas.

The bulletin contains 241 pages of text, illustrated by 11 quarto plates of halftones.

Dr. Böse describes the following formations and new species, from the base up, ranging from the base of the lower Permian to near the middle of the upper Permian.

1) Wolfcamp formation, with *Daraelites texanus*, *Uddenites schucherti*, *Uddenites minor*, *Gastrioceras modestum*, *Schistoceras diverse-costatum*, *Paralegoceras incertum*, *Agathiceras frechi*, *Marathonites vidriensis*, *Marathonites sulcatus*, *Marathonites j. p. smithi*, *Vidrioceras uddeni*, *Vidrioceras irregulare*.

2) Hess formation, with *Prothalassoceras welleri*, *Marathonites hargisi*.

3) Leonard formation, with *Medlicottia whitneyi*, *Gastrioceras altudense*, *Perrinites vidriensis*, *Perrinites compressus*, *Paralecanites altudensis*.

4) Word formation, with *Medlicottia burckhardti*, *Gastrioceras roadense*, *Paraceltites multicostatus*, *Agathiceras girtyi*, *Adrianites marathonensis*, *Stacheoceras bowmani*, *Stacheoceras gilliamense*, *Waagenoceras dieneri*.

No. 1 is called the zone of Uddenites; No. 2, zone of Prothallassoceras; No. 3, zone of Perrinites; No. 4, zone of Waagenoceras.

On table I is given a correlation table of the Permo-Carboniferous cephalopod-bearing beds of the world, and the position of the Texas beds in the column.

The previously known genera, Daraelites, Paralecanites, and Adrianites are added to the American Permian fauna, and also a true

species of Waagenoceras, those formerly assigned to that genus being shown to belong to a new genus, Perrinites. The following new genera, or subgenera, are described: Uddenites of the Medlicottidae; Marathonites, Vidrioceras, and Perrinites of the Arcertidae; Prothallassoceras of the Thalassoceratidae. While there might be a difference of opinion as to whether these should have generic rank, they are undoubtedly groups of species deserving recognition, and seem to be sharply characteristic of horizons. These horizons may be zones, though they should not be given that rank until they are shown to have interregional significance.

Dr. Böse has enriched his work with numerous critical comparisons with all known kindred Permian ammonoids, so that in the future paleontologists will have an easier time in determining relationships and stratigraphic positions of this group. The species and genera are all fully described and beautifully illustrated.

This contribution should take rank with that of Karpinsky on the *Artinsk* fauna of the Ural Mountains, and of Gemmellaro on the Sicilian Permian, and make Texas a classic region for the study of late Paleozoic ammonoids.

JAMES PERRIN SMITH

La Face de la terre. PAR ED. SUESS, Traduit avec l'autorisation de l'auteur et annoté sous la direction de EMMANUEL DE MARGERIE. Tome III: 4e Partie (Fin) avec un Epilogue, par P. Termier, de l'Academie des Sciences. Also, Tables générales de l'ouvrage. Paris: Librairie Armand Colin, 1918. Pp. 1361–1724 and 1–258.

An event of no little importance to geologists has been the issue of the concluding parts of *La Face de la terre*, the French edition of *Das Antlitz der Erde* by Eduard Suess, by many considered the greatest treatise upon geological science since the founding of modern geology.

The complete French edition of this great work now comprises no less than 13,437 imperial octavo pages, 12 colored plates, and 583 figures in the text. Suess's work exists complete therefore in English and French, as well as in the original German edition and the first volume has been done into Italian. The importance which attaches to the French edition lies in its great superiority over the original, and this not alone because of its better dress, but because the translator has supplied a vast amount of original material out of a mental equipment

for such work which is today unrivaled in the world. This material has been introduced in footnotes, while rendering a most faithful translation of the original text and, further, enriching the work with 487 illustrations, or more than four times the original number in the German text.

The making of this French edition of a great philosophical work has extended over twenty-five years and has involved an amount of painstaking labor such as is seldom assumed by a savant of the high scientific attainments of Dr. de Margerie, a former president of the Geological Society of France.

The initial volume of the text appeared in 1897 and was introduced by that master-mind which has contributed so much to French and especially Alpine geology, M. Marcel Bertrand; and now the concluding part is most appropriately closed after an interval of twenty-two years by an epilogue from the pen of M. Pierre Termier, likewise a profound student of those problems with which this *tour de force* especially deals. There is propriety in here translating a few lines from Bertrand's Preface and Termier's Epilogue. In the former we read:

> One of our masters said to me one day a propos of a work of one of our colleagues which had greatly interested us, "He is perhaps the one who has best comprehended Suess." This expression appeared to me to be under its simple and unpremeditated form the most striking tribute to the author of the *Antlitz der Erde*. . . . . The *Antlitz der Erde* brings together the work of an entire century. It sets forth the state of knowledge acquired about the globe which we inhabit. It shows with samples in hand that the era of groping has passed and that the grand features of the earth's face are now known to us; it determines the frame into which henceforth each new observation can take its place and acquire its full value. . . . . It [Suess's method] has been able to show the relationships and establish the connections from one limit of our hemisphere to the other, which, for example, had not before been perceived even from one boundary of France to the other. M. Suess has known how to elevate the fundamental features to a sufficient altitude to be seen above the complex details of their surroundings.

Dr. de Margerie had brought his labors upon this great work to a conclusion when the hostilities of the world-war were coming to an end with the signing of the armistice. It is altogether natural and proper therefore that M. Termier's Epilogue should take account of the new race psychology based upon revelations which have struck deep into the souls of us all, and to those of Frenchmen more than of any others. He says:

The publication of this work, the French edition of *Das Antlitz der Erde*, has been completed in mourning. The epilogue which I had been asked to write, and which formerly in happy years I had dreamt to offer to the old master as a tribute of admiration, affection and gratitude, will, alas, be neither read nor heard by him; and in penning these lines I can put into them neither the enthusiasm nor the joy of my dream, because the hour is sad and too much blood and too many tears have flowed upon the terrible way where humanity drags along.

Eduard Suess died at Vienna during the night of the 25–26 April, 1914; passed away peacefully, without suffering, painlessly, without having any presentiment of those disasters which were about to descend upon Europe. Many will agree with me in thinking that he did well to die in the care-free spring, the forerunner of a summer of massacres. Altogether good, generous, devoted to others, evidently made for sweetness and tenderness, he would have suffered atrociously to see what we have seen, to see entire peoples seized with madness, the face of the earth ravaged and blood-soaked, the hate of races which he believed abolished exasperated even so as to desire extermination; to see this impassable and indestructible barrier erected across Europe to separate the friends of yesterday, those who collaborated in the works of peace, of life, of brotherhood; those who would have forgotten their ancient frontiers . . . . and who now are enemies for how long a time—Great God! He has known nothing of these things, he has appeared to fall asleep in the quiet of his home in the heart of a city prosperous and happy, in the silence of the peaceful night, at the end of April, in this time of the year, ... Yes, in truth, the hour was favorable for men to depart and enter quietly into dissolution: he has done well to die.

It would be idle to deny that Suess has advanced hypotheses to which he adhered with the greatest tenacity, but which have not stood the test of time, such, for example, as his idea of the horst. In a biographical note published in this journal shortly after the death of Suess the reviewer wrote of the *Antlitz:*

The honest critic must frankly admit that, great as is this masterpiece of geological generalization, it suffers from two rather serious defects. Its author was almost too clever as advocate and parliamentarian and was, moreover, not without bias. With a manner altogether masterful, he could dismiss as it were with a wave of the hand important evidence which was unfavorable to maintenance of his thesis and, with equal ability, could magnify the weight of much less valuable or unimportant observations. Again, his great work suffers from a bewildering detail and an enumeration of localities too small to appear upon maps outside the original articles but upon which the conclusions are absolutely dependent, so that the reader is prevented from following the author's argument.

Termier's tribute to the distinguished translator of the *Antlitz* is well merited and may here take the place of the poor words of the reviewer. He continues:

I recall my astonishment and the admiration which I immediately conceived for the character of Emmanuel de Margerie, still unknown to me, upon that day of the year 1890 when Marcel Bertrand said to me the simple words: "De Margerie has the intention of translating the *Antlitz*, you will see that he will go to the end." Once more Marcel Bertrand has been a good prophet.

Open now the French edition alongside the German edition and compare them volume by volume, chapter by chapter. You will be amazed, not alone at the scrupulous exactitude of the translation, not alone by the reverent fidelity, truly filial, of the disciple in retaining the accent of the master and reproducing his thought even to its exact shade, but even more at the magnificent prodigality with which the disciple has enriched the work of Eduard Suess. The farther one penetrates into the work, the more this enrichment becomes manifest. In place of tiring, of exhausting himself, the translator expands his erudition and feels his enthusiasm growing, and here it is that he adds to each fact cited by the author ten other facts which complete the first and place it in the full light. So that the French edition which guards in the body of the text the moderation and the clarity of the German text, offers to its reader in addition a world of documents, notes, maps, or sketches of which each is in its proper place and supplies valuable information.

Thus you will understand the affection of Eduard Suess for Emmanuel de Margerie. I have never spoken to the master of his French translator without seeing the tears appear in his splendid eyes, where they appeared to reflect the majesty of the universe.[1]

In truth, Emmanuel de Margerie has deserved well of science. He has opened fully and definitely to all scholars of the Latin race the access to the "magnificent temple." Thanks to him into our half of the scientific world Suess's work will penetrate with greater richness and comprehensibility, and in the other half many a savant who has read *Das Antlitz der Erde*, will prefer *La Face de la terre*.

WILLIAM HERBERT HOBBS

Geology of Missouri. By E. B. BRANSON. University of Missouri Bulletin. Vol. XIX, No. 15. 1918. Pp. 172.

This bulletin gives a summary of the geological history of Missouri, with a very brief description of the principal formations and the principal

[1] The same warm affection Suess cherished for Marcel Bertrand, and the reviewer can testify that his eyes welled with tears as he referred to the darkened years which closed the career of this great French savant. It is worth our while to remember this in these days of race hatreds without parallel.

geographic changes which the state underwent in the course of its history. It is illustrated by numerous paleogeographic maps and some excellent diagrams and sections. This brief summary of the geological history of the state is very welcome to those who live beyond the confines of Missouri, as it doubtless is to many residents of the state.

One chapter deals with the life of the various geologic periods. Others deal with the minerals and rocks of the state and with its economic geology. The later chapters outline the range of industries dependent upon geologic materials, and give a summary of the value of the mineral products. The range of mineral resources is perhaps larger than most of those unfamiliar with the geology of the state have known.

R. D. S.

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